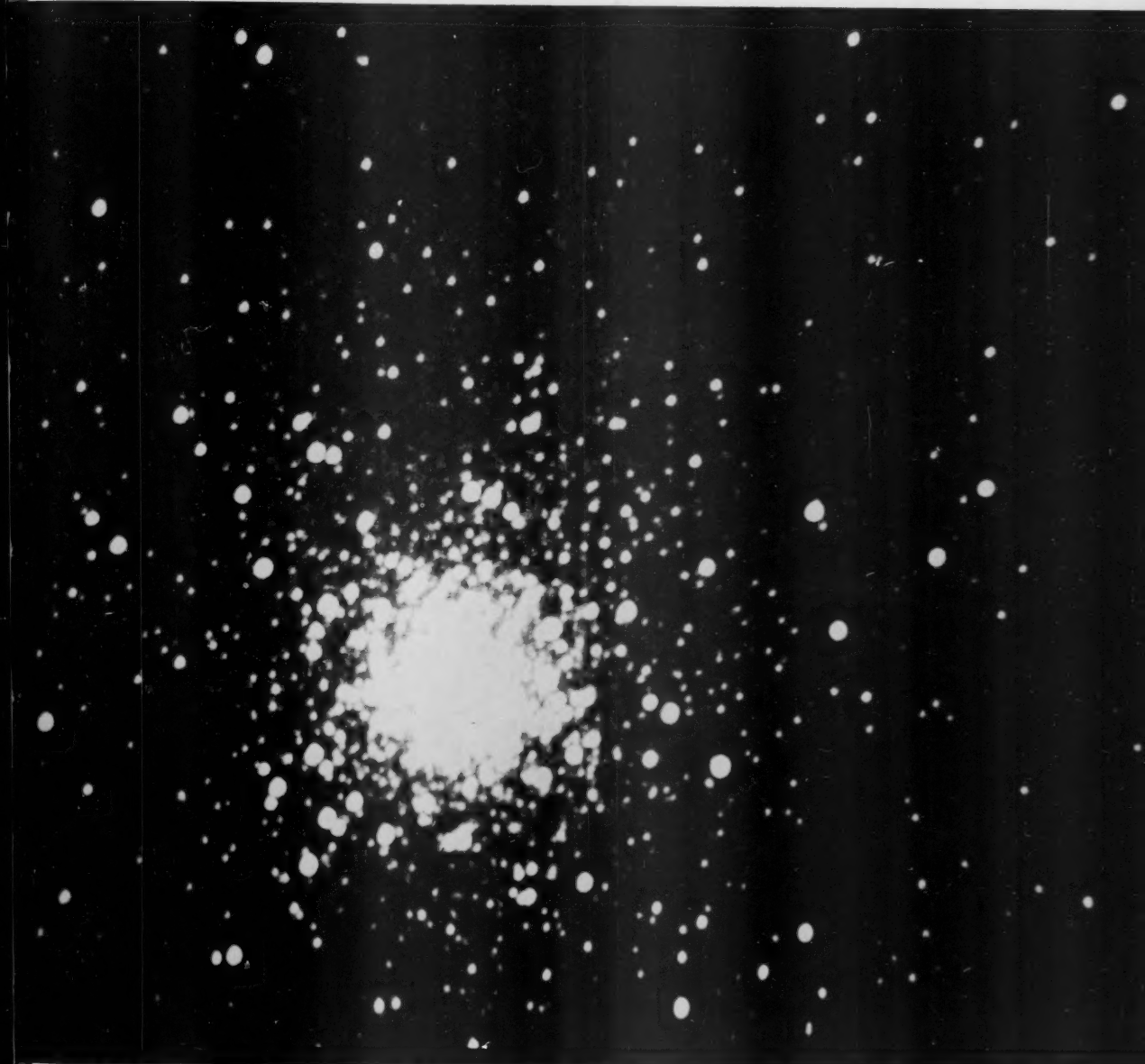
SCIENCE

20 October 1961

Vol. 134, No. 3486

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE



Instrument Issue

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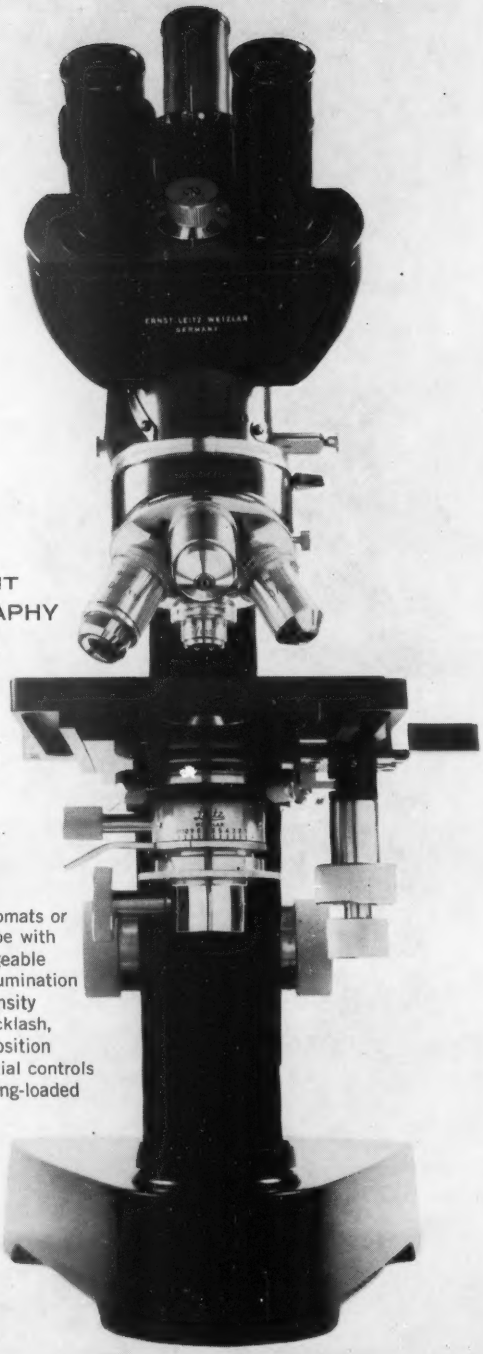

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5 FLUORESCENCE **6** PHOTOMICROGRAPHY

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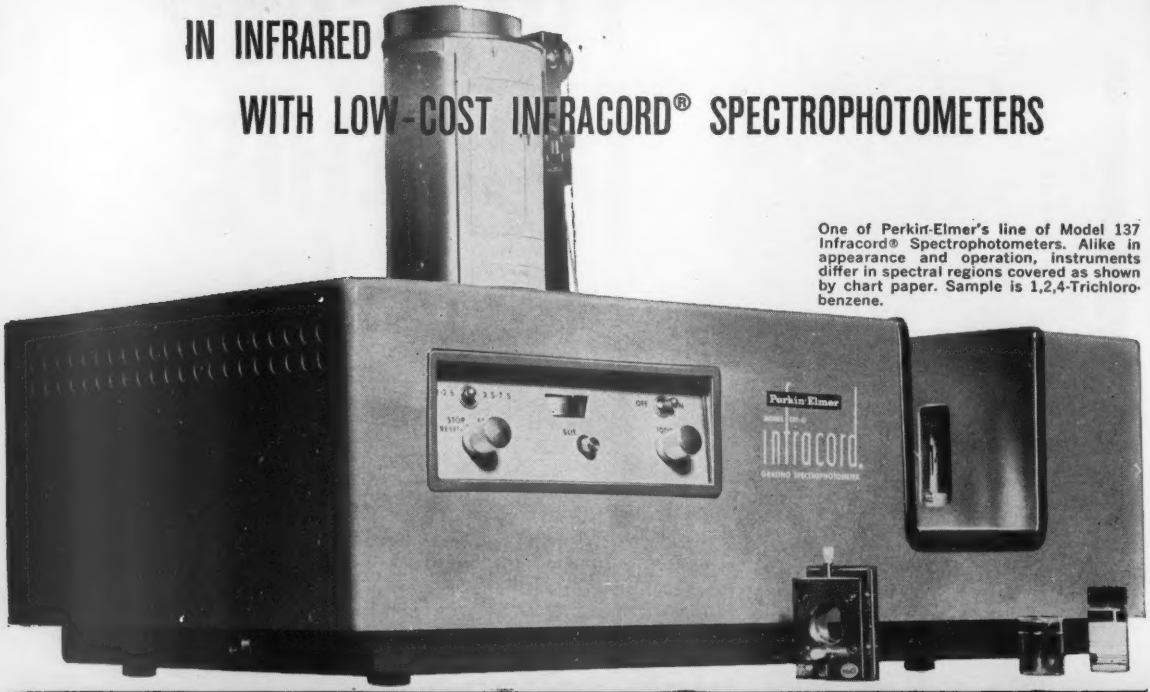
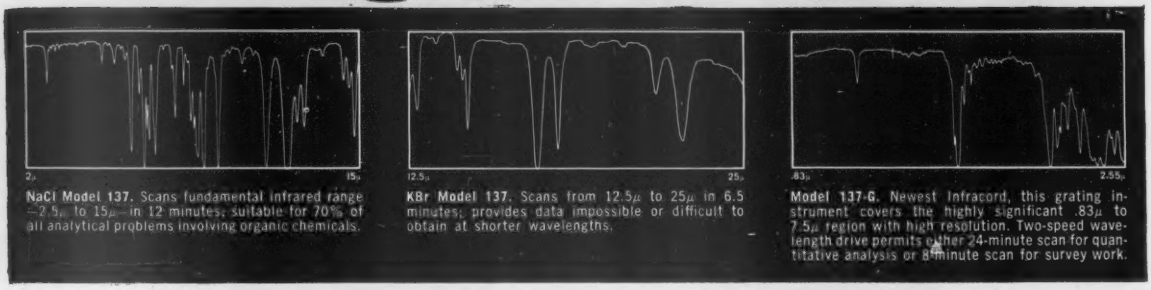


One of Perkin-Elmer's line of Model 137 Infracord® Spectrophotometers. Alike in appearance and operation, instruments differ in spectral regions covered as shown by chart paper. Sample is 1,2,4-Trichlorobenzene.



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20 October 1961, Volume 134, Number 3486

SCIENCE

Cover

Globular star cluster M3 in yellow light, taken at Kitt Peak 19 March 1961 with a GL-7629 image orthicon. Exposure time, 8.5 seconds. See page 1165.

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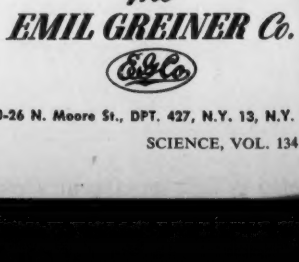

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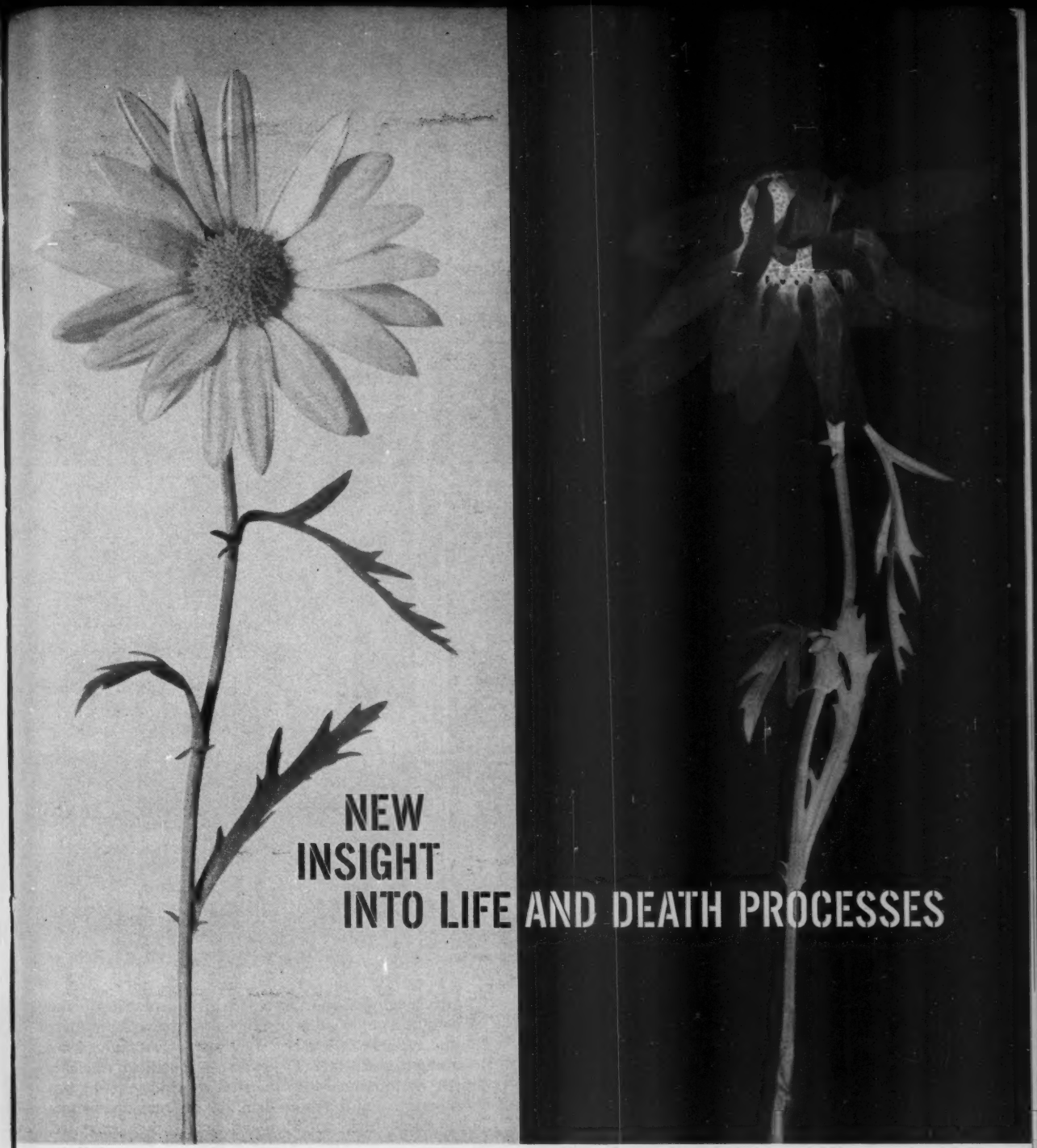

NEW INSIGHT INTO LIFE AND DEATH PROCESSES

Although the innermost secrets of life and death still remain a mystery, continuing investigations are helping us gain better insight into these fundamental processes. One of the newer techniques being used successfully to study these phenomena is EPR (Electron Paramagnetic Resonance) Spectroscopy.

Several recent experiments using EPR to detect the presence of free-radicals have helped confirm new theories concerning the nature of the life and death processes which previously had been based on rather inconclusive evidence.

For example: EPR has been used to study photosynthesis, an important life process in **Chlorella pyrenoidosa** (an algae). It was demonstrated that more than one pigment must be activated by light for efficent photosynthesis to occur. And in another experiment, the results of EPR analysis were used to show a strong correlation between the death process and free radical concentration in freeze-dried **Serratia marcescens** (a common bacteria).

Perhaps EPR analysis can be of value in your investigations. If you would care to discuss possible applications, please contact the INSTRUMENT DIVISION.

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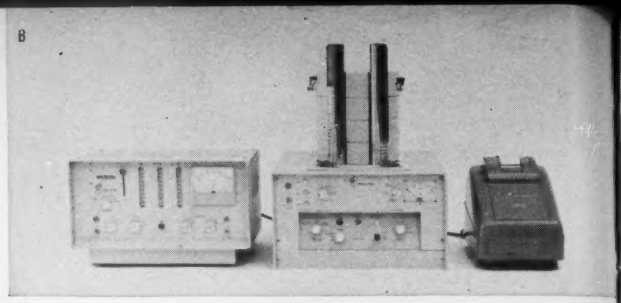

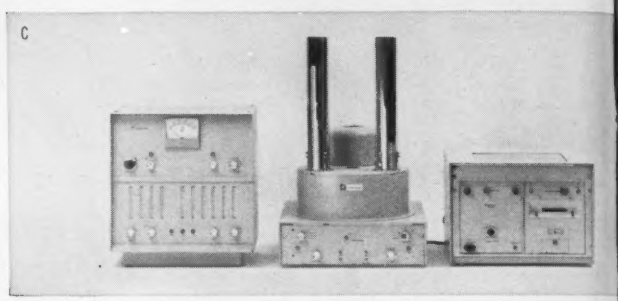

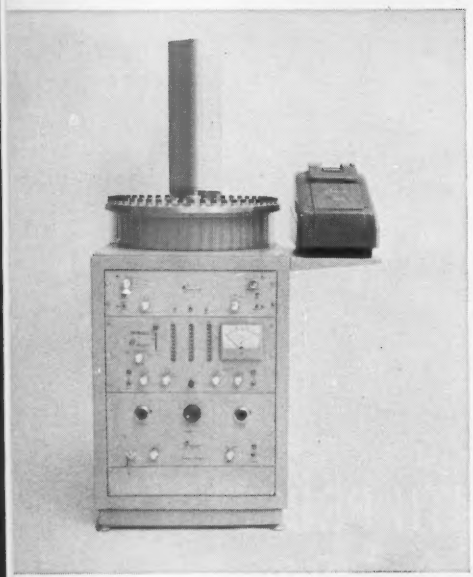

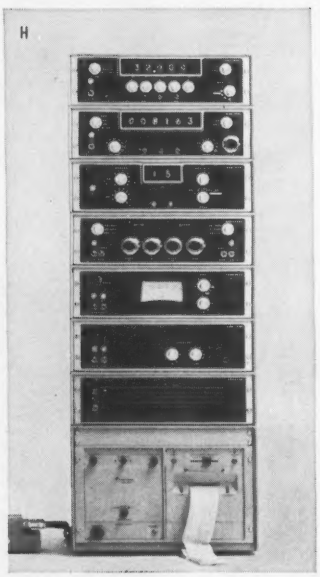

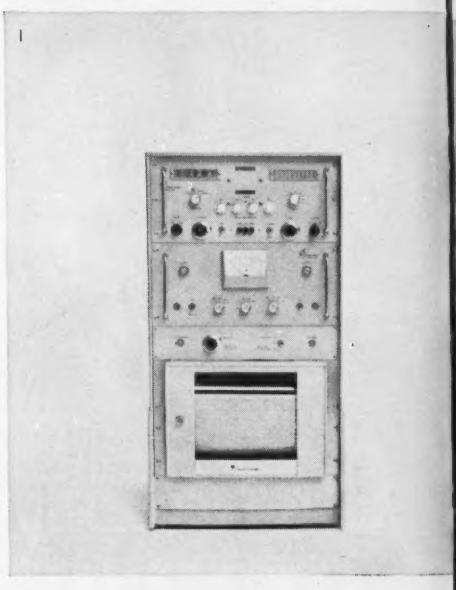

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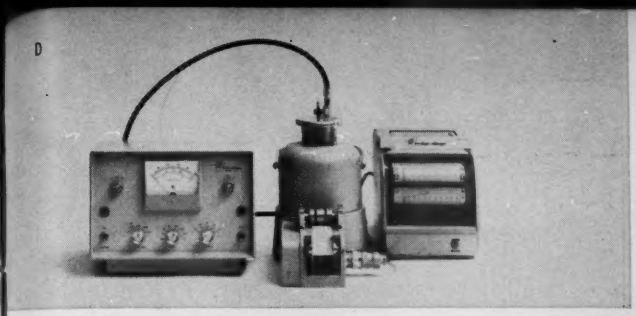

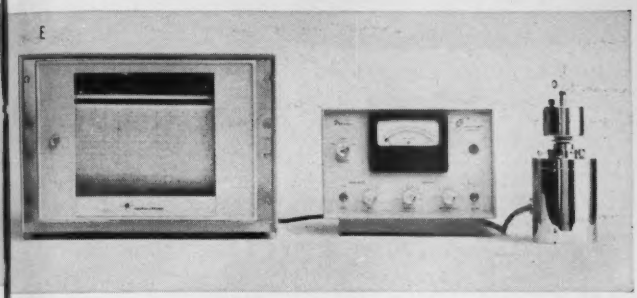

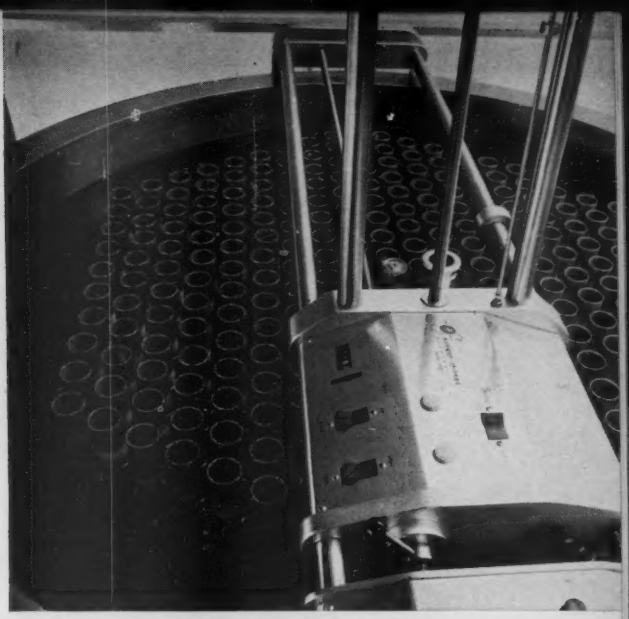

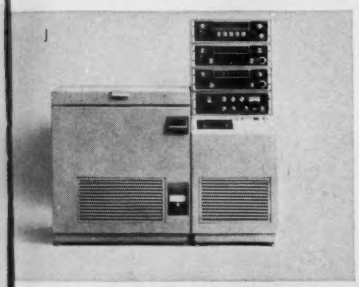

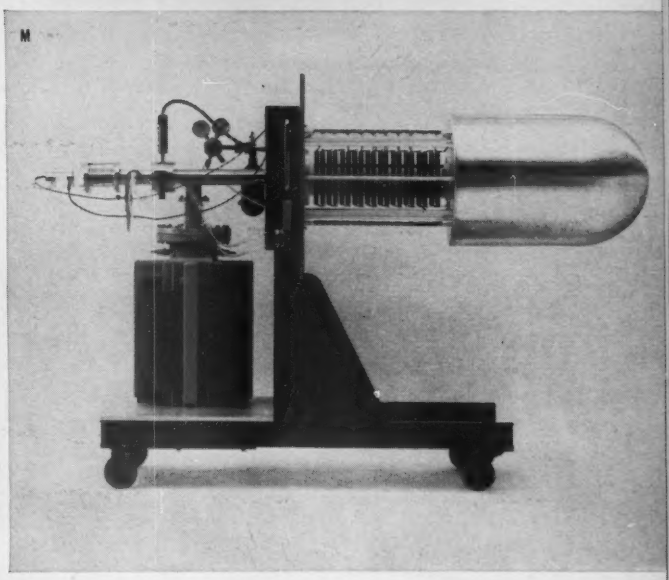

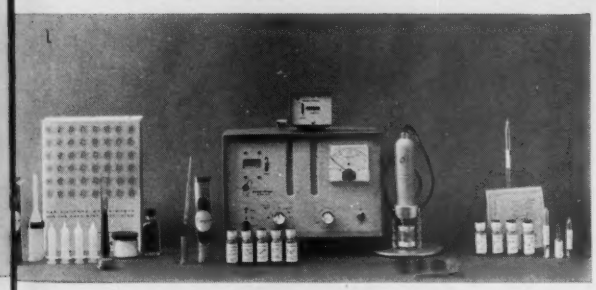

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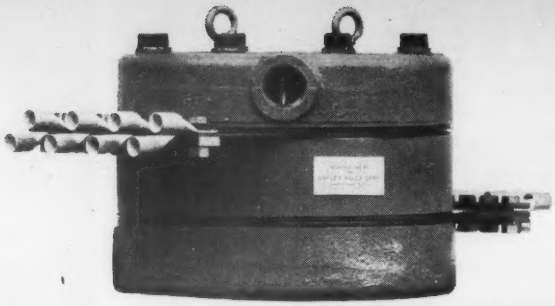
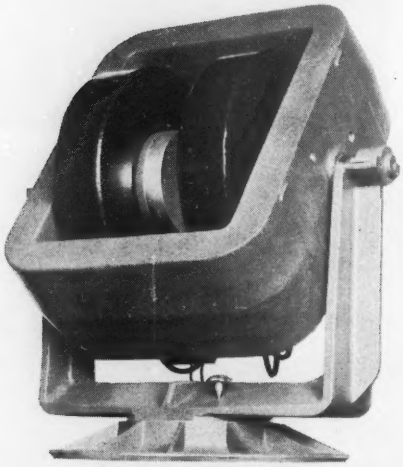
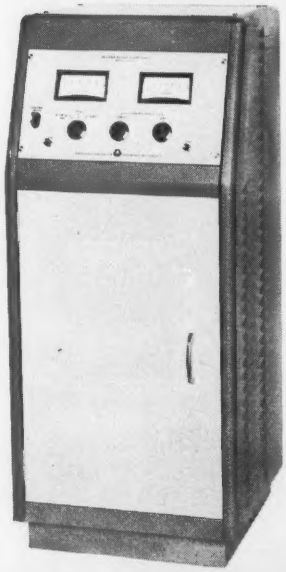


Model HF-26 2" Bore Solenoid Magnet

Model L-128 12" Electromagnet



Model HS-1050 Magnet Power Supply



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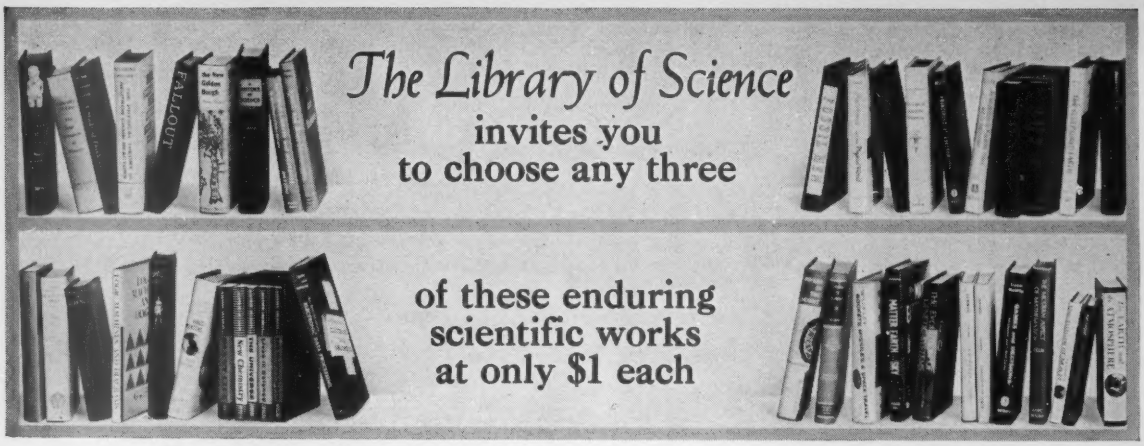

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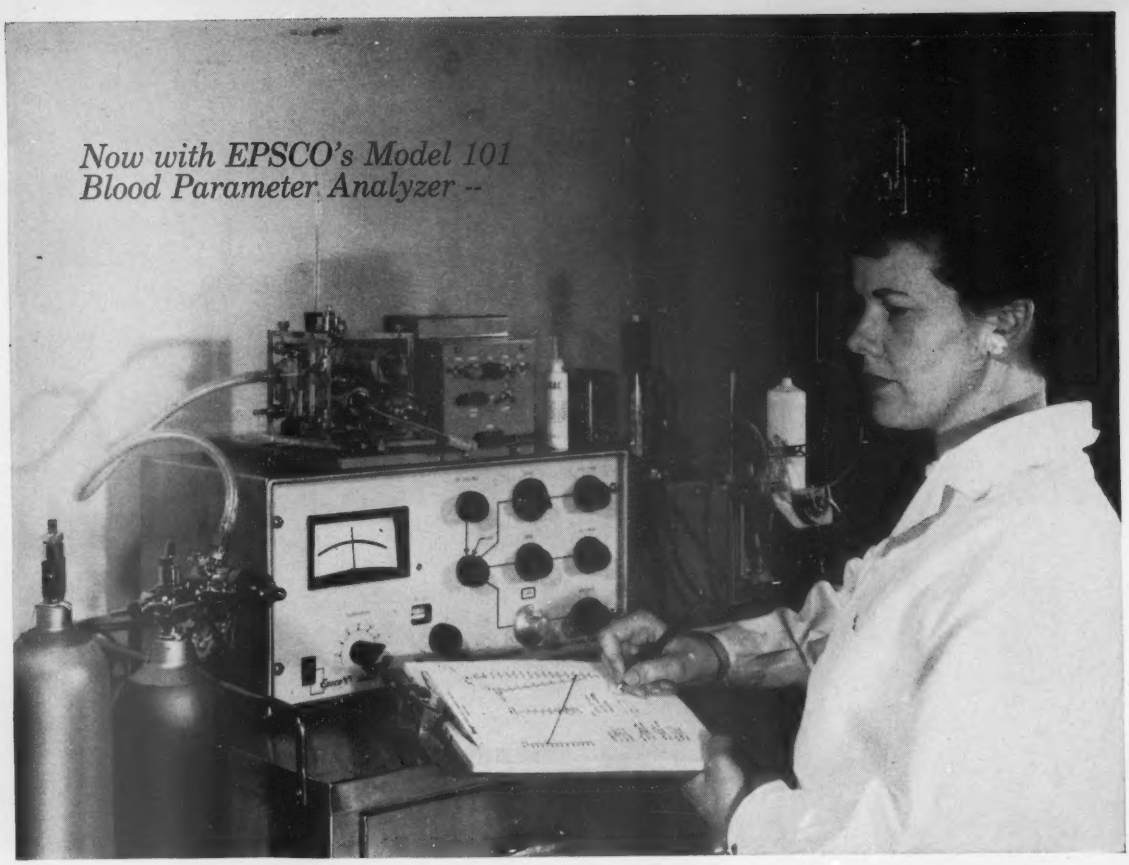

Make direct measurements of *pH*, pCO_2 & pO_2 from whole blood in only 3 minutes

The Epsco Model 101 Blood Parameter Analyzer has been developed to satisfy the need for greater speed and accuracy in determining physiologically significant whole blood parameters. Sensitive and readable without interpolation to better than 0.002 pH, it provides direct readings in millimeters of mercury of pO_2 in 1 minute and pCO_2 in 3 minutes. The unit may also be used as a gas analyzer, and for measuring changes in O_2 and CO_2 in various biologic fluids. A completely integrated system, Epsco's Blood Parameter Analyzer realizes speeds not possible with chemical techniques, and accuracies unobtainable by infra-red analyses of expired air.

SIMPLE, RELIABLE OPERATION — The Analyzer requires minimum "set-up" time. Electrodes are calibrated by using readily available standardizing gas. Controls are functionally-grouped for operating ease, and lock-equipped to safeguard calibration settings. Built-in design features prevent instrument drift that may be caused by room temperature changes; and an internal standard reference cell protects against long-term drift. Since nomographs or calibration curves are not required, the chance of operator error is reduced.

The unit has connections for an external recorder . . . permitting continuous recording of changes in pH, pCO_2 or pO_2. Specially calibrated meter faces are available for uses requiring direct readout.

WIDE APPLICATION — Especially useful in clinical laboratories doing pH and blood gas analyses, the unique capabilities of the Blood Parameter Analyzer make it a valuable aid in surgery, cardiac catheterization, pulmonary function determinations and anesthesia studies. Versatile, accurate and fast, the Analyzer has been designed and built to the exacting Epsco standards — established during years of experience in advanced military and industrial instrumentation programs — that assure the greatest possible reliability in operation.

201-1 A

FOR MORE INFORMATION on Epsco's Model 101 Blood Parameter Analyzer, write for free bulletin.

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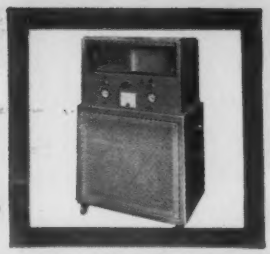
AMSCO Microbiological Equipment



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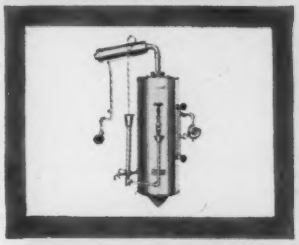

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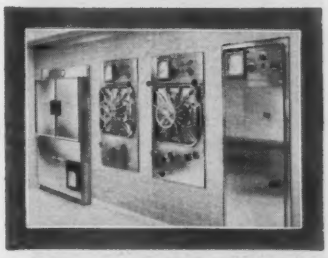
DEIONIZERS — Complete line ranging from 2 to 1000 gal./hr.



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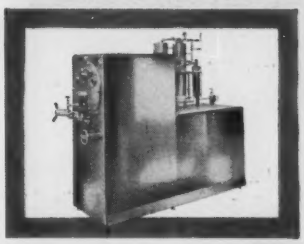

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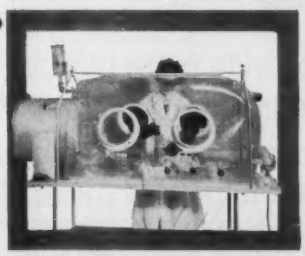

For good reason more and more universities, pharmaceuticals and industrials confidently specify AMSCO Freeze Dryers, Sterilizers, Water Stills and other specialized microbiological equipment. Each is designed and built to accomplish a specific job better . . . more dependably . . . and with less time and attention from the staff.

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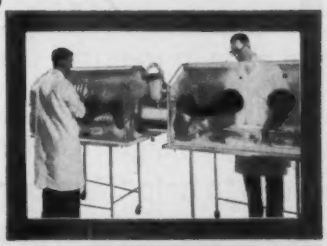
Meanwhile we'll be happy to send along literature on any of the equipment illustrated.



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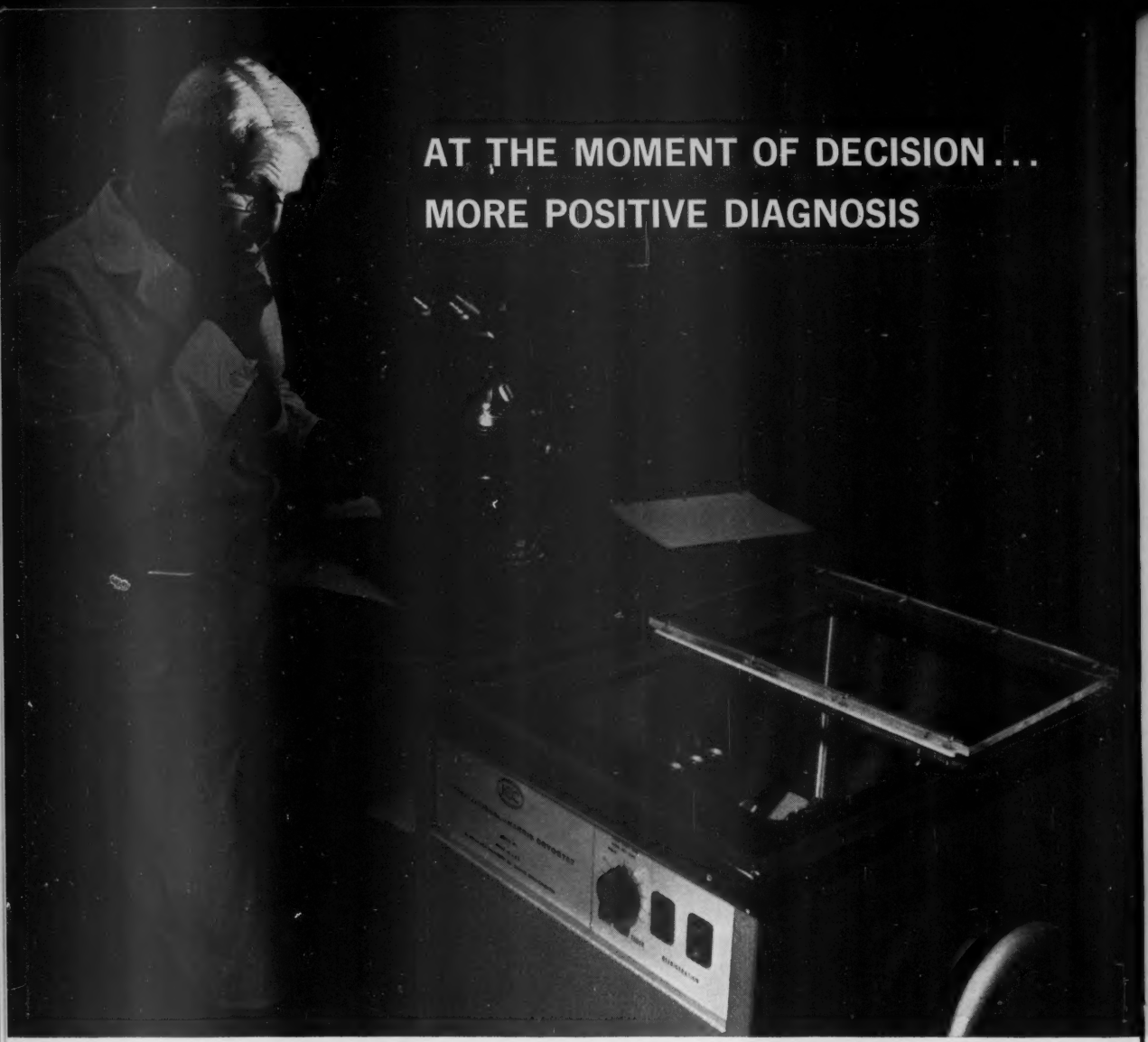

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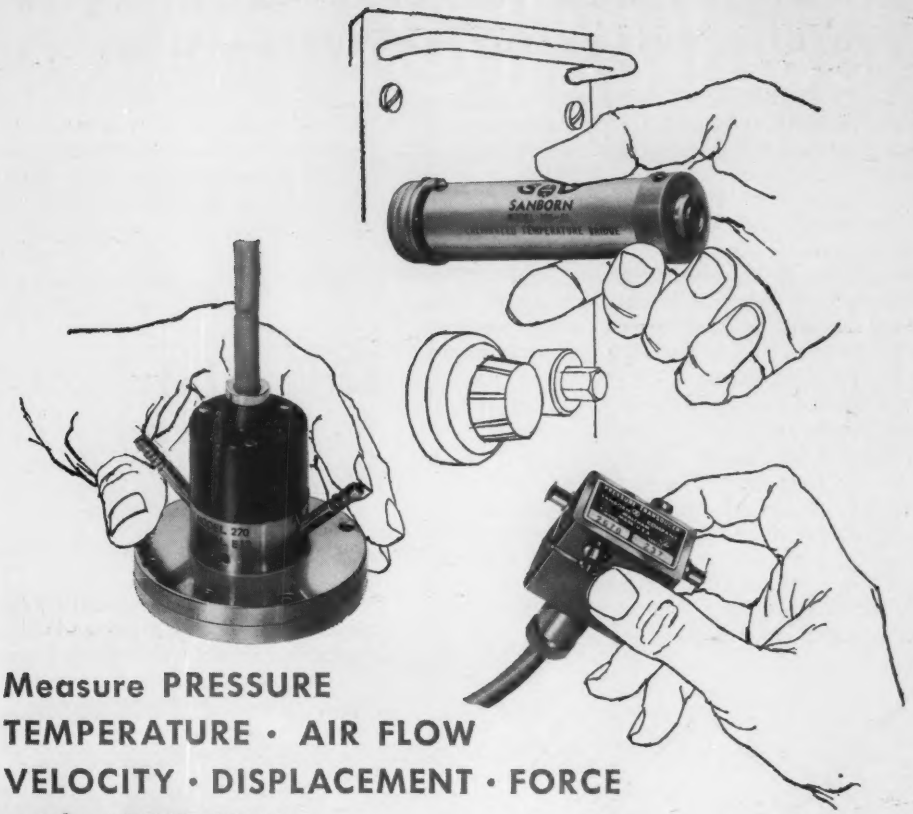

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In addition, Sanborn offers pneumograph and pulse wave attachments, heart sound microphones, linear velocity and displacement transducers, and transducers for force measurements in myographic studies. For complete information contact your nearest Sanborn Branch Office or Service Agency — or write Manager, Research Instrument Sales, Medical Division.

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ATTENUATED TOTAL REFLECTION

A promising new infrared sampling technique especially suited for analyzing films and solids

At the 1959 Spectroscopy Symposium in Bologna, Dr. J. Fahrenfort of the Shell Research Laboratories in Holland discussed the application of attenuated total reflection to infrared spectroscopy. Greatly intrigued by his work, we at Connecticut Instrument Corporation have spent several months studying the technique and developing practical equipment for its routine application in the infrared laboratory. While we have just begun to scratch the surface of potential uses for the ATR method of sampling, we have learned enough to believe that it will soon become as useful to the spectroscopist as the KBr pellet technique.

In a somewhat oversimplified form, attenuated total reflection may be explained as follows:

Assume that a beam of radiation is passed into a prism so that it is totally reflected from the back face, as in Figure 1. It has been shown, both mathematically and by physical measurements, that some portion of the energy of the beam escapes from the totally reflecting face and then is returned into the prism. It is almost as though the ray had a wave front of a finite width and behaved as shown in the diagram.

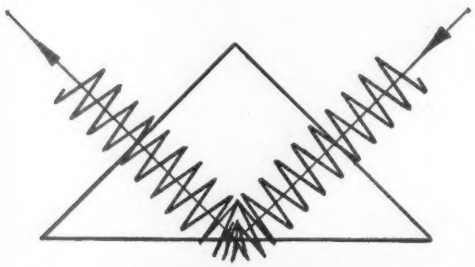

Figure 1. Schematic of attenuated reflection effect

It would appear that, if an absorbing material is placed in contact with the reflecting surface, the energy that escapes temporarily from the prism would be selectively absorbed, much as in a transmission spectrum. Under the proper conditions this is indeed the case.

The absorption-like spectra obtained by this method have two important and unique features:

1. The band intensities are the equivalent of an extremely shallow (5 microns or less) penetration into the sample.

2. They are completely independent of the sample thickness.

As manufacturers of infrared cells, it comes as a considerable relief to find a sampling procedure that eliminates precise and extremely short pathlengths as a requirement for infrared sampling!

Because of these characteristics, it is apparent that the ATR technique will have widespread application in the infrared analysis of solid materials and other strongly absorbing substances.

To make practical application of the ATR technique we have developed an attachment that will fit into most commercial infrared spectrometers and which has a reflecting surface available from which the spectrometer beam may be reflected at an adjustable angle of incidence (Figure 3).

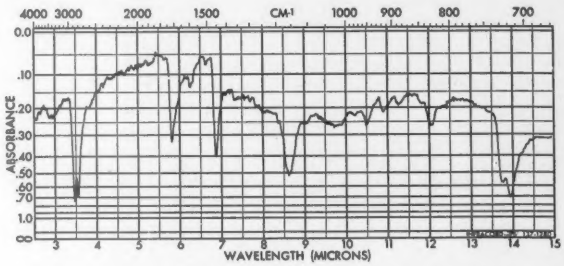

Figure 2. ATR spectrum of Carnauba wax made with a pressed plate

We have worked out several different sampling techniques for handling solids and liquids, including an expendable Frisnel type reflector plate upon which samples may be permanently deposited. The spectrum in Figure 2 shows some typical results.

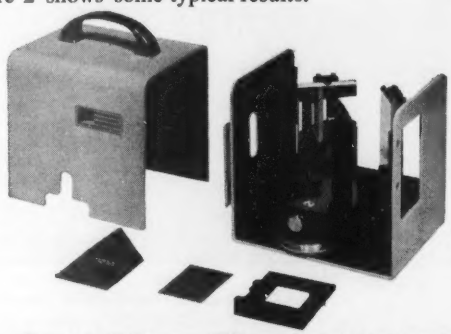

Figure 3. CIC's new ATR attachment, cover removed, showing sampling accessories

The ATR technique offers fascinating possibilities to the spectroscopist in enabling him to obtain spectra on samples that are difficult or impossible to analyze by conventional techniques — plastics in the solid state, strongly absorbing liquids, such as water solutions, naturally occuring materials and inorganics — to name a few.

The Model ATR-1 attachment developed by C I C will enable the spectroscopist to experiment with this new technique for a moderate investment. It is simply installed and extremely versatile. We will be pleased to send you full details.

CIC

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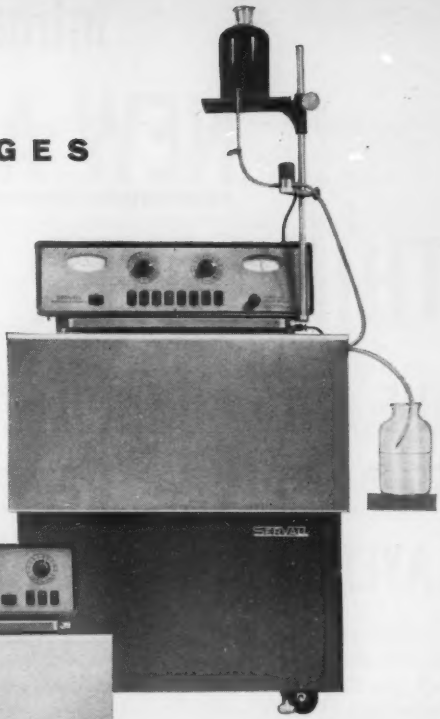
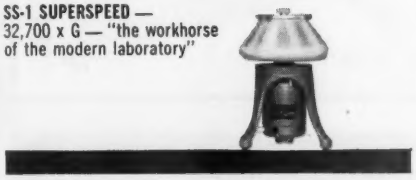


RC-2 AUTOMATIC SUPERSPEED REFRIGERATED — up to 37,000 x G with SS-34 Rotor. Accepts five other rotors. Shown set up for KSB Continuous Flow operation. KSB system may also be used with SS-1, SS-3 and SS-4

SS-1 SUPERSPEED — 32,700 x G — "the workhorse of the modern laboratory"



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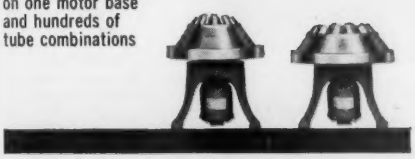

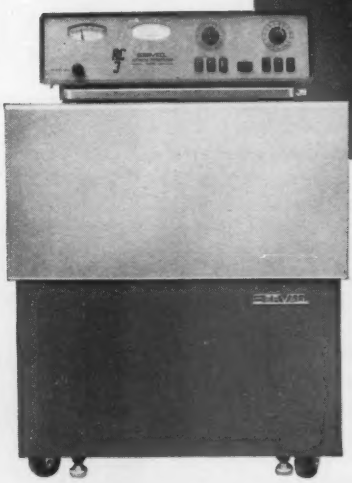

RC-3 GENERAL PURPOSE AUTOMATIC REFRIGERATED — 5,000 rpm, — 5,100 x G. 70 seconds to operating speed; 70 seconds to stop. Reduces thirty-minute jobs to five minutes. Ideal for general, routine, and blood work

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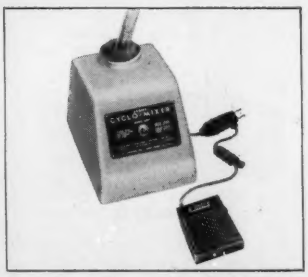

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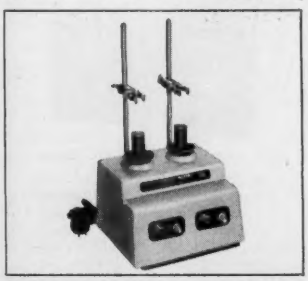

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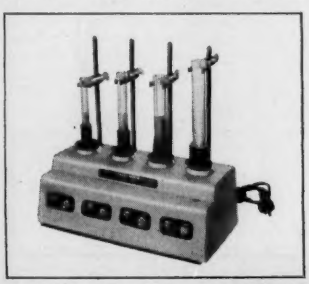

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The gel material used as supporting medium may be hydrolyzed starch, agar, or the synthetic polyacrylamide Cyanogum (Reg. American Cyanamid Co.). Each of these media gives a different type of resolution, and in many problems it will be advantageous to employ all three concurrently or successively; the procedure then becomes analogous to two-dimensional chromatography. Migration thru a gel slab in the horizontal position introduces undesirable gravitational-convection effects in the migrating zone; therefore, a vertical gel slab is preferable, providing that a proper supporting apparatus is available.

COUNTERCURRENT DISTRIBUTION

Counter-current extraction is a method of analyzing or separating the components of a mixture by dissolving in one phase of a two-phase solvent system, and extracting it with the other phase. This effects a relative separation of the components according to the distribution co-efficients of each. Repeating the extraction many times in a systemic manner multiplies the effects of even small differences in distribution coefficients, so that closely similar substances can be separated. The separated volumes may be analyzed by any applicable method, preferably one which gives the total quantity of solute in each volume. Thus the total volume of solvent may be titrated when dealing with a mixture of acids. The most generally applicable, when non-volatile solutes are concerned, is the determination of the weight of solute in each fraction. It should be noted, however, that macro quantities of material are not required. Extremely low concentrations may be used, which may be far below those required for weight determinations. Necessary, of course, are sensitive analytical methods, such as color reactions or ultraviolet absorption. With such methods, counter-current extraction can analyze quantities as small as those in any other analysis. Results using low concentrations may be even more accurate than those with high concentrations owing to a closer approach to the laws of ideal solutions from which the following equations are derived. Counter-current extraction follows very exactly the Distribution Law

$$Ki = \frac{(i)\,1}{(i)\,2}$$

where K_1 is a constant characteristic of the compound i; $(i)_1$, and $(i)_2$ are the concentrations of compound i at equilibrium in phase 1 and phase 2 of the solvent system. This fact allows a very mathematical analysis of the quantitative results obtained in counter-current extraction, and permits the direct comparison of experimental and theoretical results.

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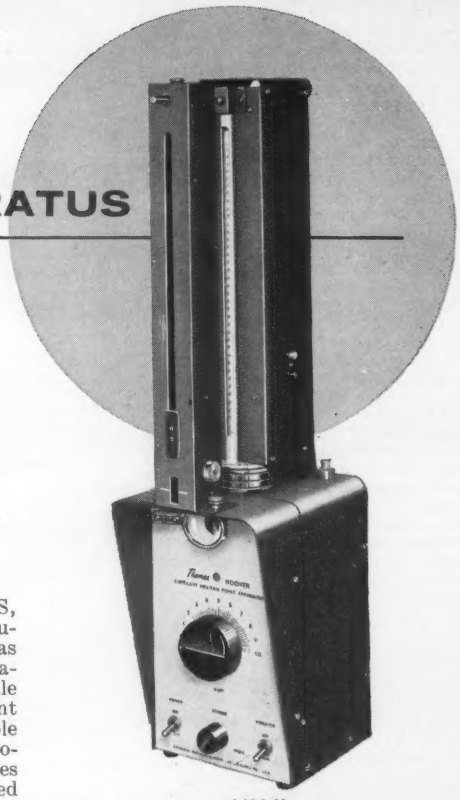


6406-M.
Hoover Melting Point Apparatus, complete with Periscopic Reader and Thermometer Illuminator

THE HOOVER MELTING POINT APPARATUS, "Uni-Melt," which is rapidly becoming a standard instrument for determination of capillary melting points, has recently been improved to overcome fluctuation in laboratory lighting. Glareless illumination, restricted to the scale of the thermometer, is provided by an 8-watt fluorescent lamp in ventilated metal housing. The more sharply visible thermometer meniscus reduces operator eye-strain, promotes greater accuracy of individual readings and decreases the time for a series of determinations, especially when used with the Periscopic Thermometer Reader.

The Apparatus was designed by Dr. John R. E. Hoover to meet official U.S.P. requirements, and offers the following outstanding features:

Safety. Bath enclosed in cabinet except for observation port which is shielded by the magnifier. Removal of bath automatically disconnects heater and stirrer.

Rapid heating and cooling. Coiled Nichrome wire heater responds rapidly to changes in input voltage, providing rapid, lagless heat. Bath temperature can be raised rapidly to within a few degrees of the anticipated melting point, i.e., to 350°C in 6½ minutes, and then raised slowly until melting occurs. Bath can be cooled rapidly for the next determination, i.e., from 300°C to 150°C in approx. 5 minutes, by attaching compressed air line.

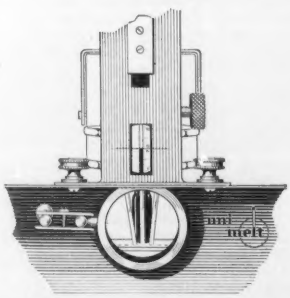
Capillary Vibrator. Recessed in top of housing. Shakes capillaries thoroughly, insuring uniform packing of sample.

Both the Thermometer Illuminator and Periscopic Thermometer Reader are available for attachment to the basic instrument. The Reader presents a magnified scale image in a window just above the sample observation port. Fusion of sample can be observed and melting temperature noted without raising the head. Thermometer meniscus can be followed by turning knob at right.

6406-H. Melting Point Apparatus, Hoover "Uni-Melt," with armored thermometer —10 to 360°C in 1°, 6 melting point standards, 4 oz. Silicone Fluid and 100 capillaries, but without Periscopic Reader or Illuminator. For 115 volts, 60 cycles, a.c. 175.00

6406-K. Ditto, with Periscopic Thermometer Reader 212.50

6406-M. Ditto, complete with both Periscopic Reader and Thermometer Illuminator 244.00



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Accessories
(For attachment to instruments already in use)

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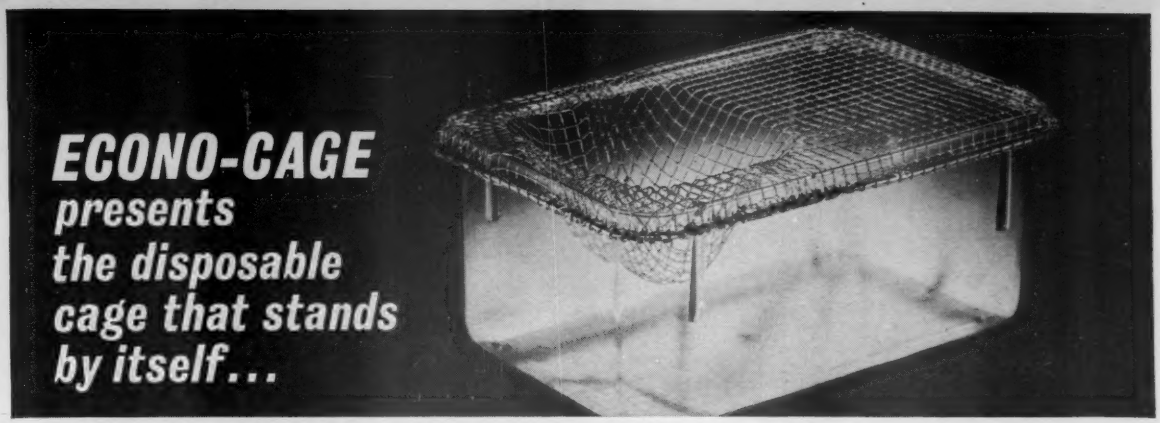

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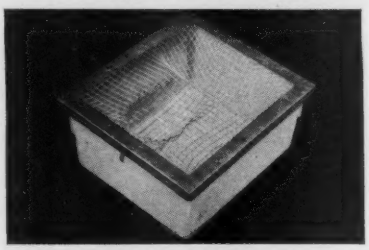

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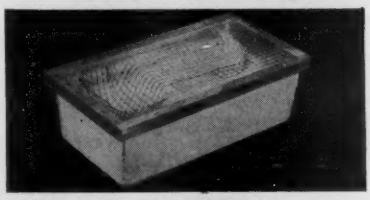
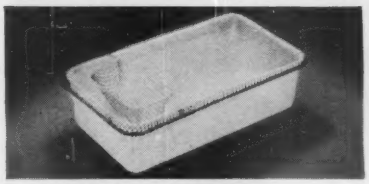
The new 50 Series Econo-Cages and lids are designed for Hamsters or rats. Dimensions are 12⅞" X 14⅞" X 6⅝" deep with room for 11 adult Hamsters per cage. The cages are available in clear Acrylonitrile-Styrene Copolymer—Econo-Cage #53, Linear Polyethylene—Econo-Cage #54 and Polypropylene—Econo-Cage #55. All 50 Series lids fit interchangeably on 50 Series cages.



ECONO-CAGE #40 SERIES

Number 40 Series cages can be used interchangeably for Hamsters and/or rats. #43 is made of clear Acrilonitrile-Styrene-Copolymer, #44 of Linear Polyethylene and #45 of translucent Polypropylene. All 40 Series lids are standard ½" mesh designed for rat housing and fit interchangeably on all 40 Series cages. All 30 Series lids also fit all 40 Series cages but have the $\frac{5}{16}$" for mice.



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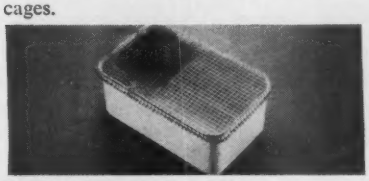
Number 30 Series cages are designed as breeding and holding cages for mice. The over-all dimensions are 19" X 10½" X 5⅛" deep. Cage #32 is made of fiberglass, reinforced by plastic. Cage #33 is made of clear Acrylonitrile-Styrene Copolymer. Cage #34 is made of linear high density Polyethylene. Cage #35 is made of Polypropylene. All 30 Series lids are interchangeable on 30 Series cages.



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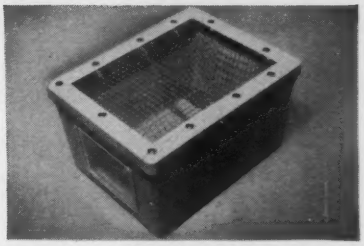
Econo-Cages in the 20 Series are designed primarily for mice. Over-all dimensions of the cages are 11½" X 7½" X 5". This cage is used for housing animals during experimentation and also as a one-to-one and two-to-one breeding cage. The cages are available in Polystyrene – new disposable Econo-Cage #21, Fiberglass, reinforced plastic – Econo-Cage #22, clear Styrene-Acrylonitrile Copolymer – Econo-Cage #23, transculent Linear Polyethylene—Econo-Cage #24, autoclavable Polypropylene—Econo-Cage #25 and Polycarbonate Resin—Econo-Cage #27. All 20 Series lids are interchangeable on 20 Series cages.



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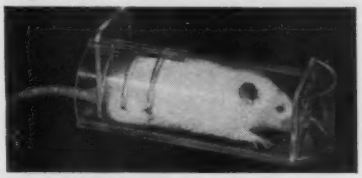

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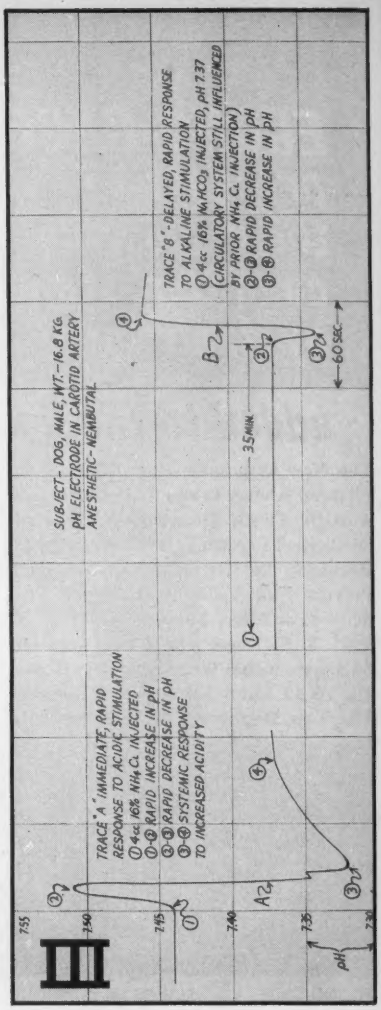

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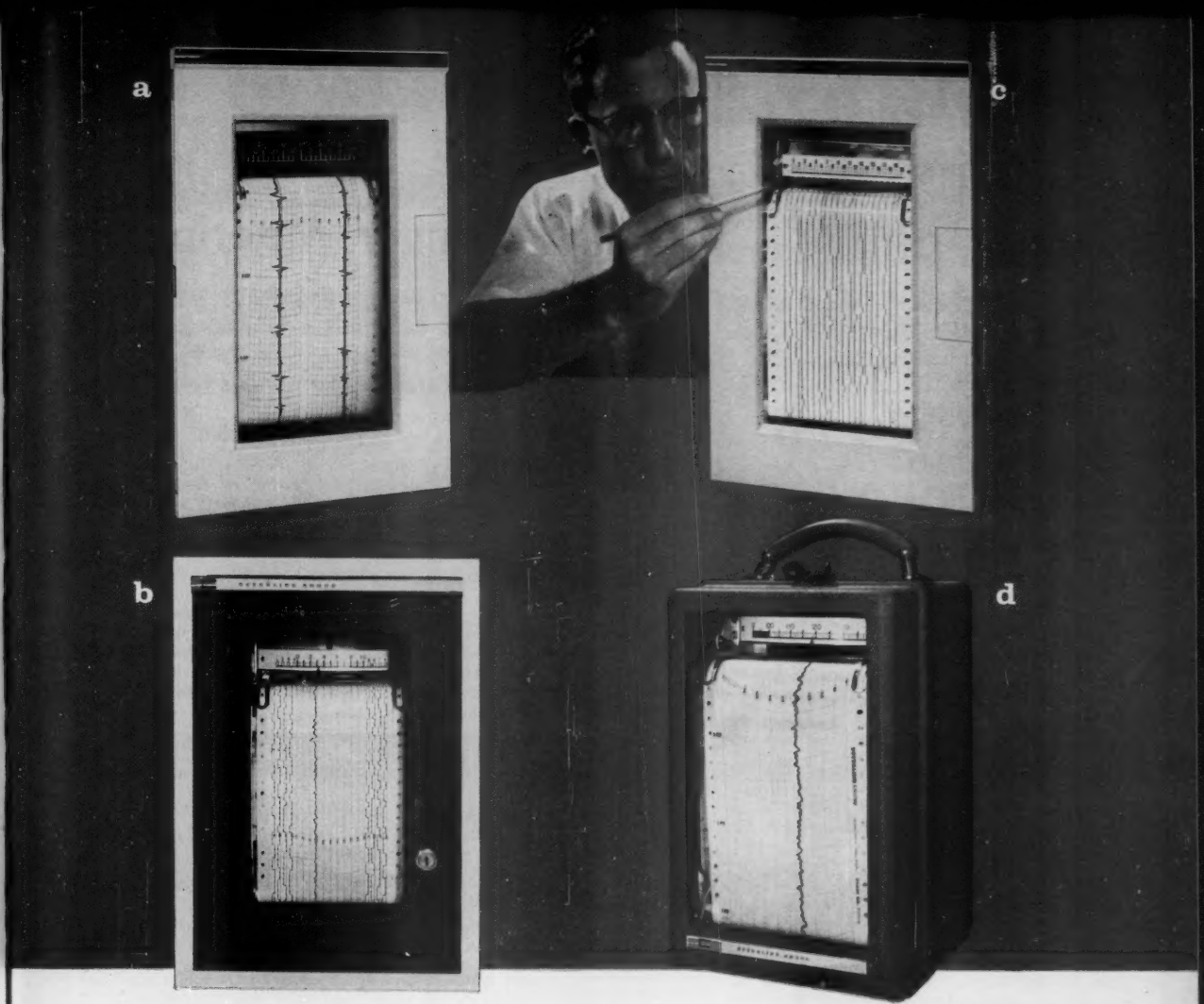

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Program Content

1. The two-session AAAS General Sessions, "Moving Frontiers of Science," Part I—Speakers: Howard A. Meyerhoff and Arthur R. von Hippel; Harrison Brown, presiding. Part II—Speakers: Halton C. Arp and E. W. Fager; Harrison Brown, presiding.
2. The 29th John Wesley Powell Memorial Lecture. Speaker: Glenn T. Seaborg; Paul M. Gross, presiding.
3. On "AAAS Day," the four broad, interdisciplinary symposia—Physics of the Upper Atmosphere; Geochemical Evolution—The First Five Billion Years; Existing Levels of Radioactivity in Man and His Environment; and Water and Climate—arranged by AAAS Sections jointly.
4. The Special Sessions: AAAS Presidential Address and Reception; Joint Address of Sigma Xi and Phi Beta Kappa by Harrison Brown; the Tau Beta Phi Address by John A. Logan; National Geographic Society Illustrated Lecture; and the second George Sarton Memorial Lecture by Joseph Kaplan.
5. The programs of all 18 AAAS Sections (specialized symposia and contributed papers).
6. The programs of the national meetings of the American Astronomical Society, American Society of Criminology, American Nature Study Society, American Society of Naturalists, American Society of Zoologists, Beta Beta Beta Biological Society, Biometric Society (WNAR), National Association of Biology Teachers, Scientific Research Society of America, Society for General Systems Research, Society of Protozoologists, Society of Systematic Zoology, and the Society of the Sigma Xi.
7. The multi-sessioned special programs of the American Astronautical Society (Hugh L. Dryden as dinner speaker), American Physiological Society, American Psychiatric Association, Association of American Geographers, Ecological Society of America, National Science Teachers Association, National Speleological Society—and still others, a total of some 70 to 80 participating organizations.
8. The sessions of the Academy Conference, the Conference on Scientific Communication, and the Conference on Scientific Manpower.
9. The sessions of the AAAS Cooperative Committee on the Teaching of Science and Mathematics, of the AAAS Committee on Science in the Promotion of Human Welfare.
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11. Exhibitors in the 1961 Annual Exposition of Science and Industry and descriptions of their exhibits.

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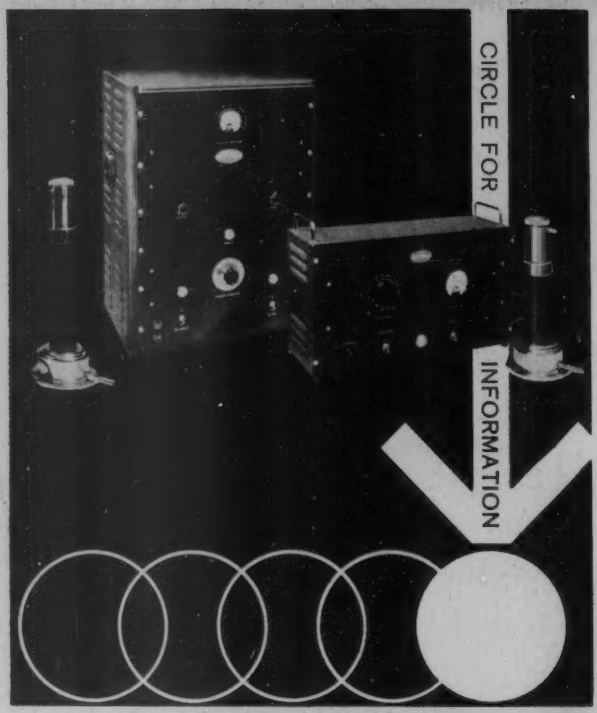

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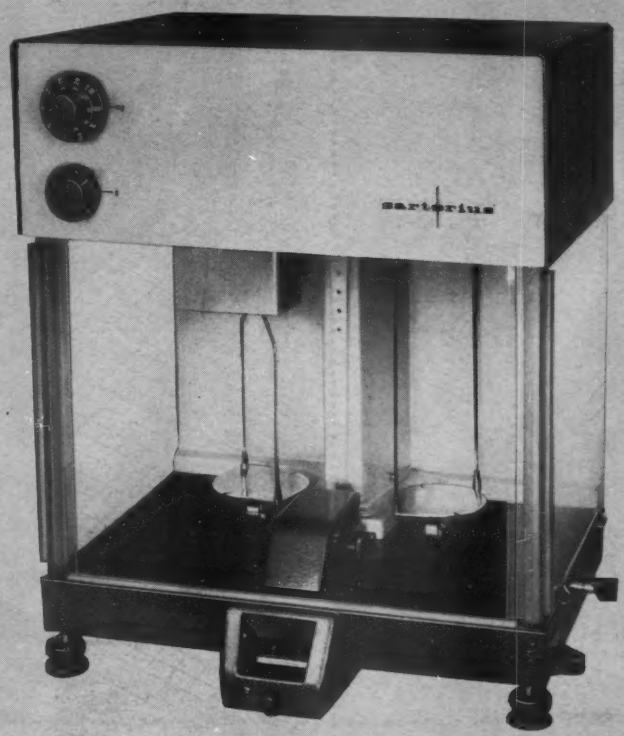

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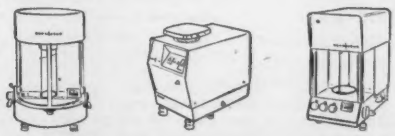

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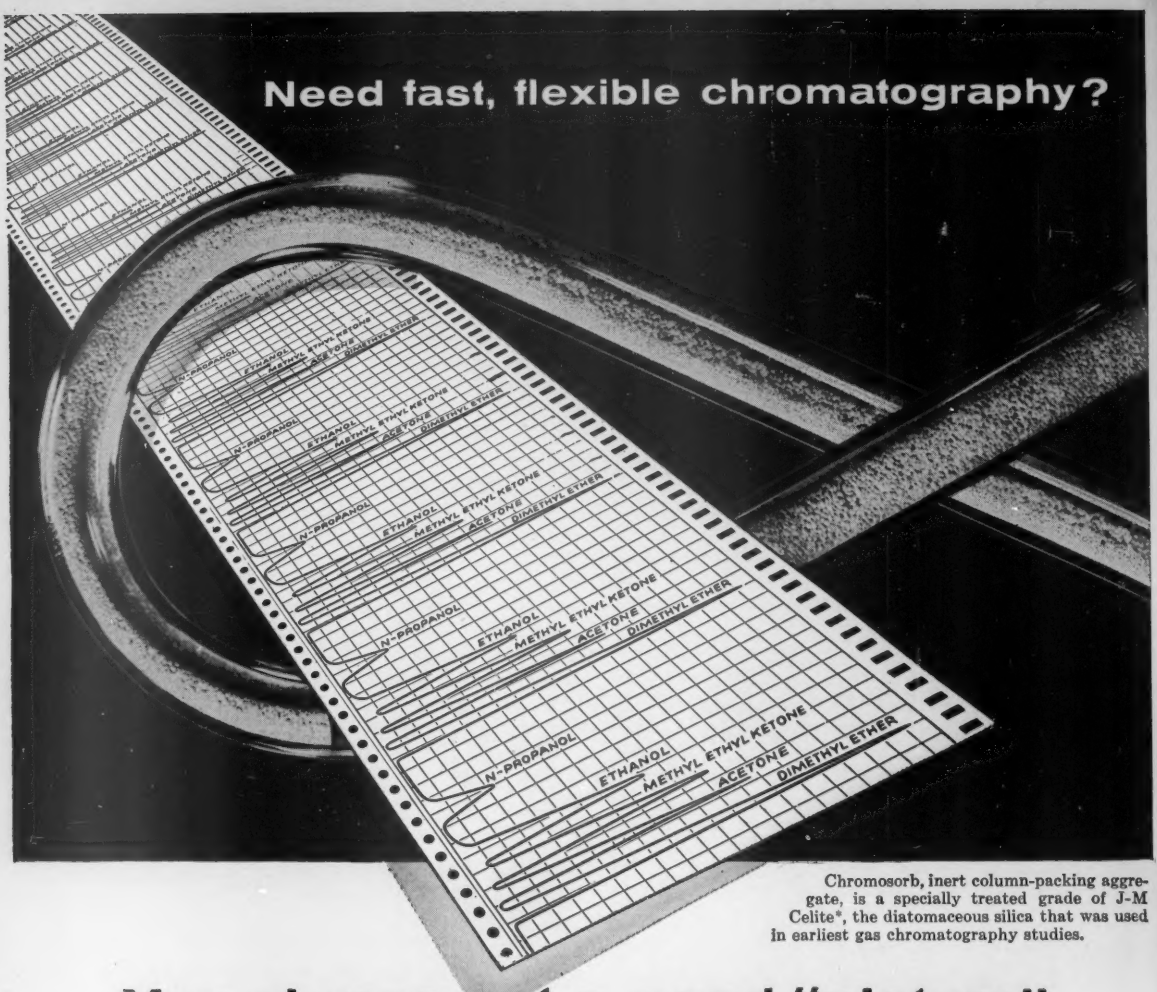

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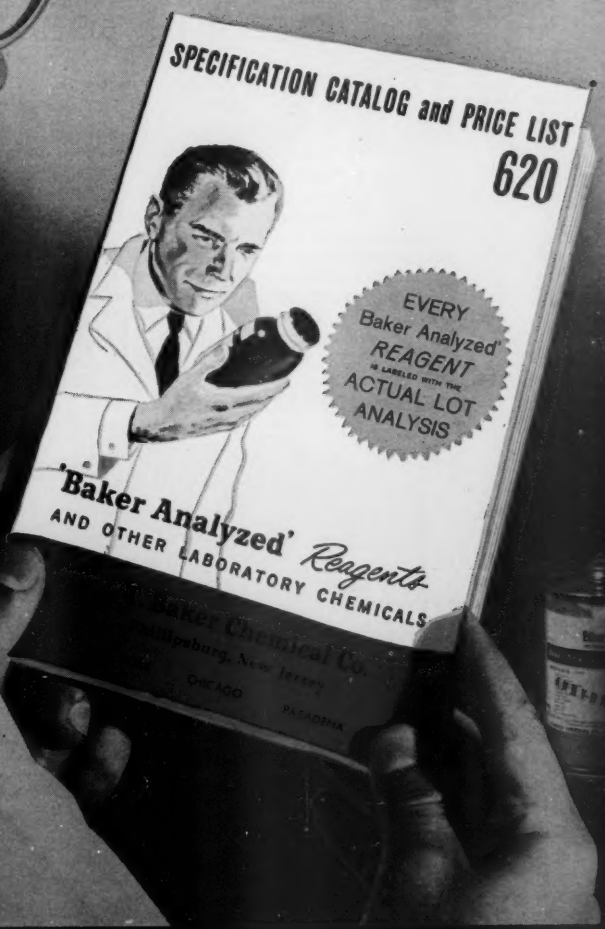

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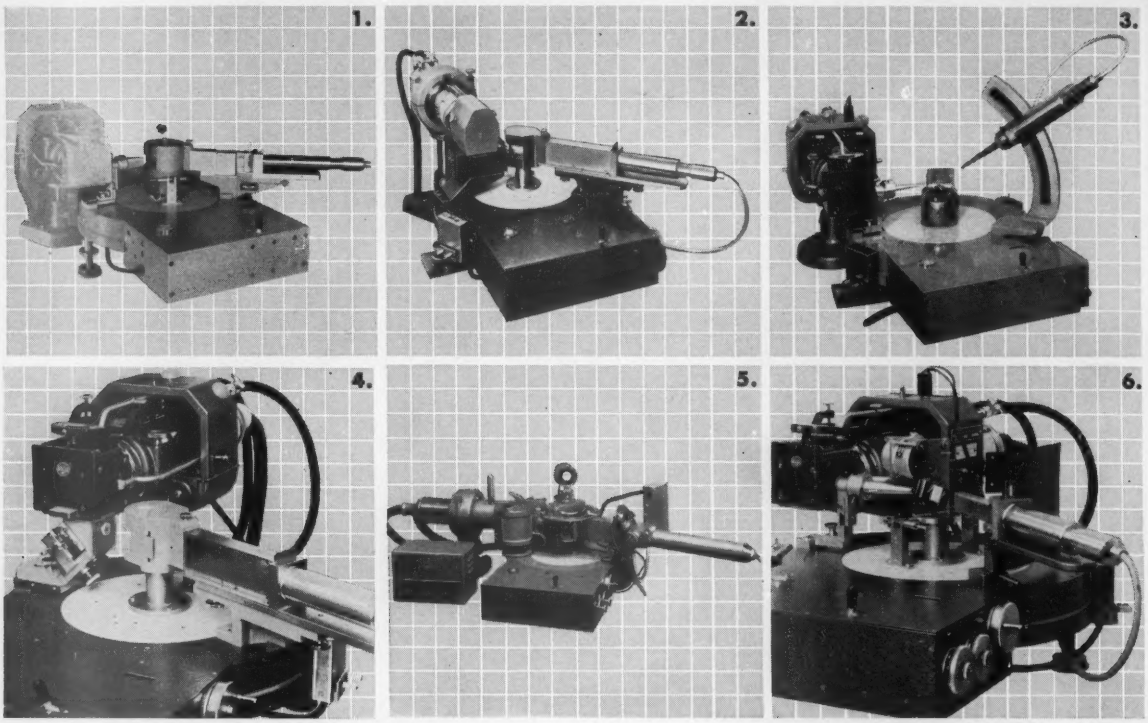

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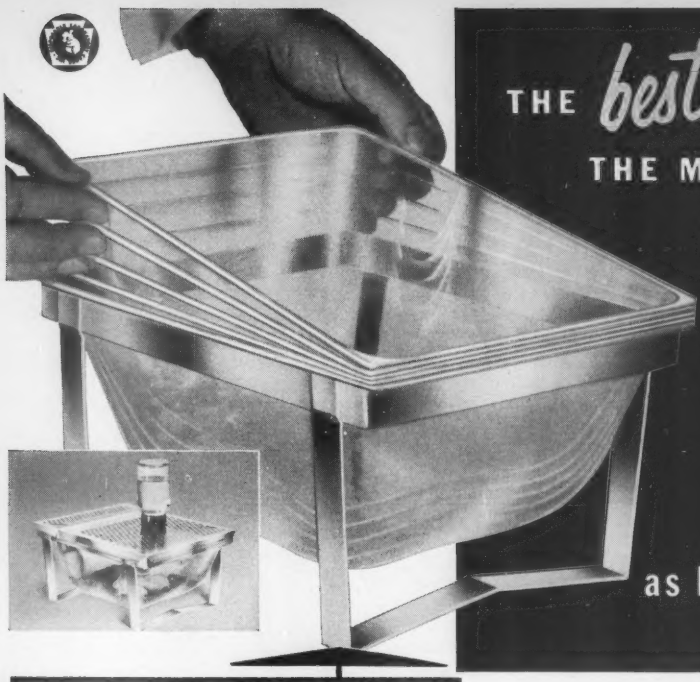

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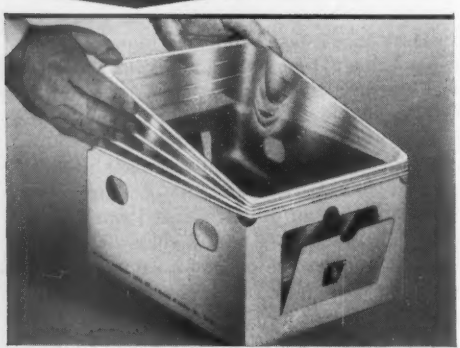

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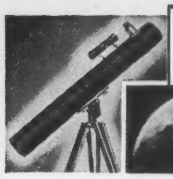

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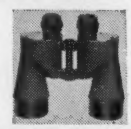

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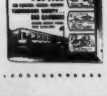

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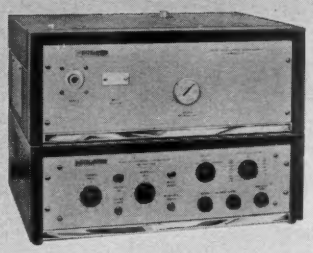

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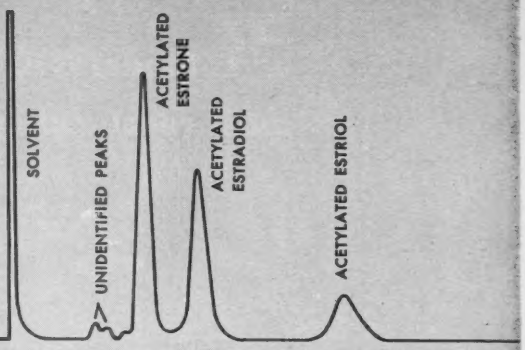

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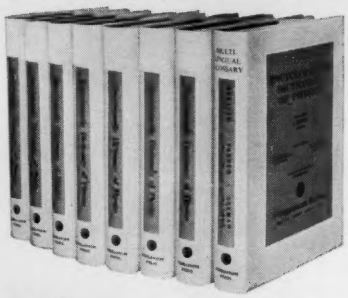

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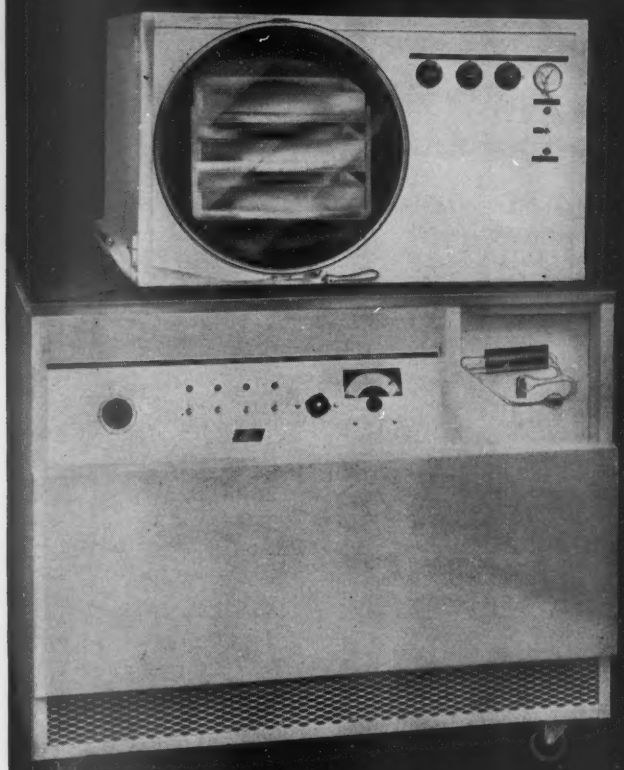

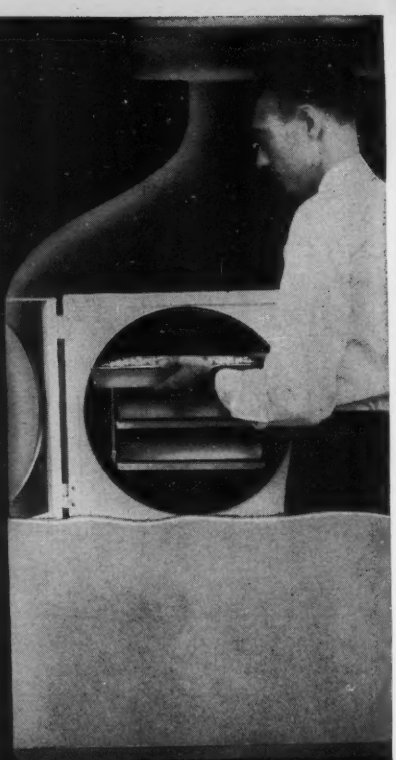

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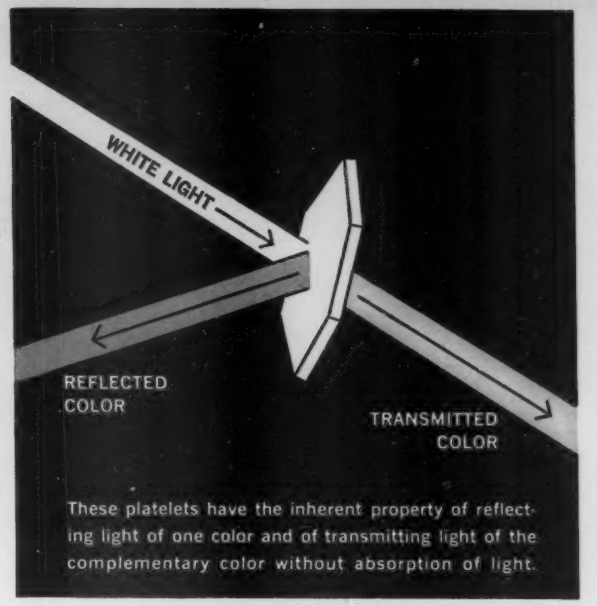

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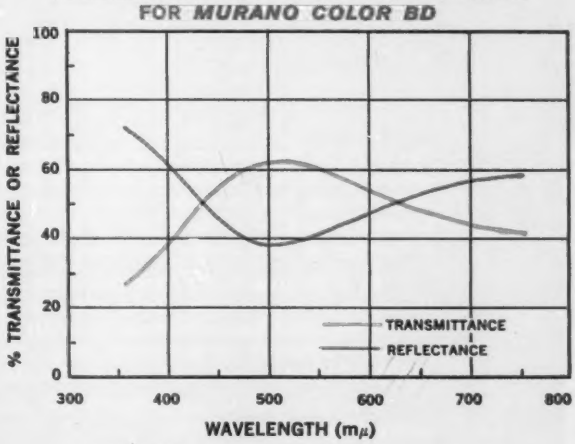

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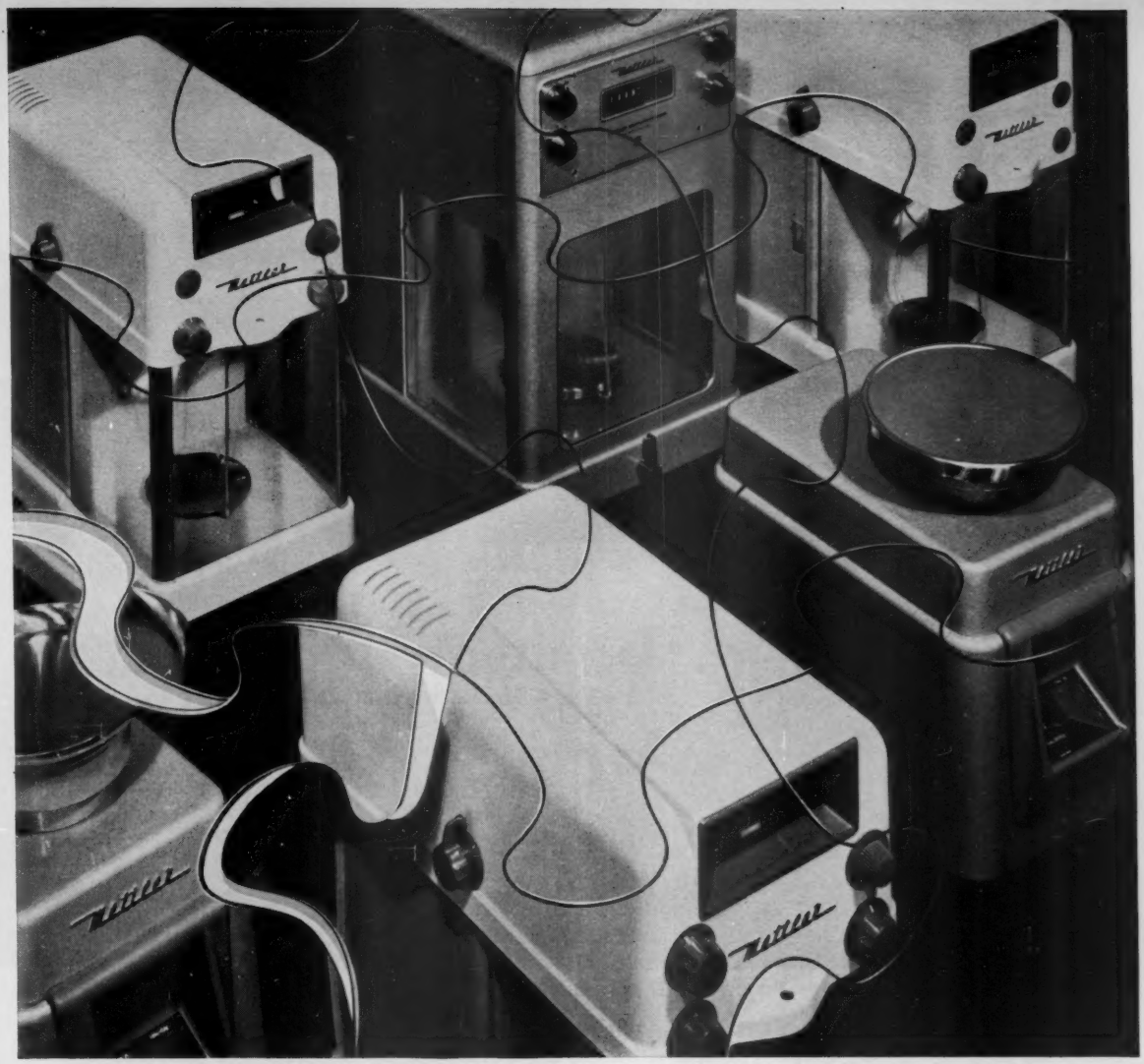

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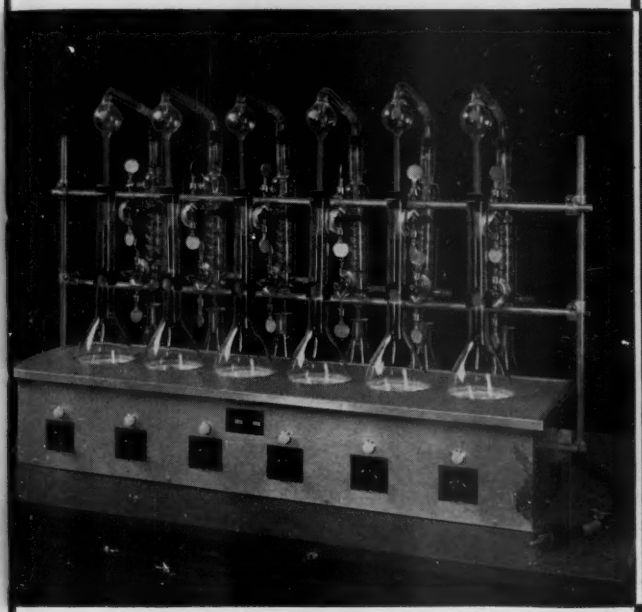
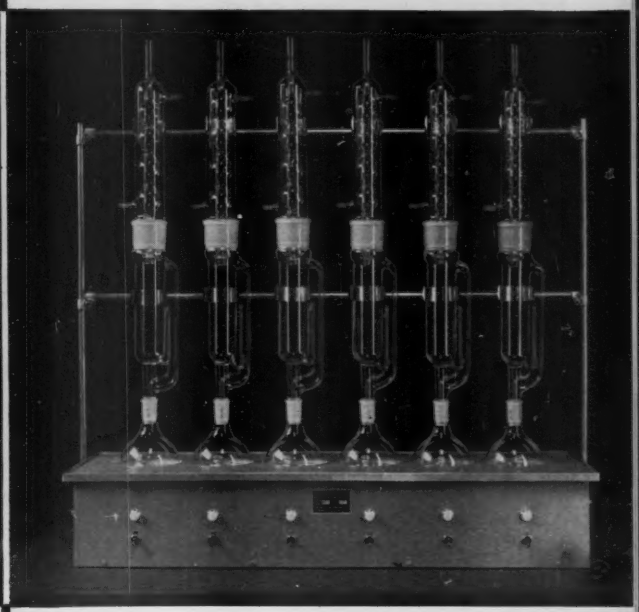
The new Soxhlet and Kjeldahl heating mantles are by-products of years of Glas-Col research in the development of safe, dependable heating equipment for pilot plant and laboratory use. Nothing has been overlooked for the safe operation of this equipment. Both new units have a beautiful anodized aluminum housing which holds six flasks. Tops are made of a resilient cork-like material to help prevent accidental mechanical flask breakage. Heating units can be individually replaced, if severely damaged by spillage of chemicals, at reasonable cost.





Kjeldahl Heating Mantle

Heat input for each unit can be individually controlled. The mantle has rugged 3-wire cord with one wire grounded to metal housing. Since wattage requirements for distilled aqueous solutions are high, the heating mantles are made from quartz fabric for safe, dependable operation.

SPECIFICATIONS

Catalog No. KJ-500
Size of flask.....500 ml
Power per unit.....325 watts, 115 volts
Price.....$350.00
Replacement heating elements.....$12.00 each

Catalog No. KJ-650
Size of flask.....650 ml
Power per unit.....385 watts, 115 volts
Price.....$370.00
Replacement heating elements.....$14.00 each

Catalog No. KJ-800
Size of flask.....800 ml
Power per unit.....440 watts, 115 volts
Price.....$370.00
Replacement heating elements.....$14.00 each

Soxhlet Heating Mantle

Since flammable solvents are most always used in Soxhlet extractions, this new heating mantle has been designed with utmost safety in mind. It utilizes Powerstat type control and is provided with rugged 3-wire cord, one wire grounded to housing.

SPECIFICATIONS

Catalog No. SOX-500
Size of flask.....500 ml
Power per unit.....250 watts, 115 volts
Price.....$285.00
Replacement heating elements.....$9.50 each

Prices for other sizes on request.
Wire, write, or phone today for complete details.

Glas-Col Apparatus Company

Dept. SC, 711 Hulman Street, Terre Haute, Ind.

World's largest manufacturer of heating mantles for laboratory, pilot plant, and production applications.

U. S. Patents . . 2,282,078 . . 2,739,220 . . 2,231,506 . . and 2,739,221

APPLICATION FOR HOTEL RESERVATIONS
128th AAAS MEETING
Denver, 26–31 December 1961

The hotels for the AAAS Denver meeting have established **special, low rates** and have reserved appropriately large blocks of rooms for this meeting. Thus everyone making room reservations for the AAAS meeting is assured substantial savings.

The list of hotels and the reservation coupons below are for your convenience in making your hotel reservation in Denver. Please send your application, *not* to any hotel directly, but to the AAAS Housing Bureau in Denver and thereby avoid delay and confusion. The experienced Housing Bureau will make assignments promptly; a confirmation will be sent you in two weeks or less.

If requested, the hotels will add a comfortable rollaway bed to any room, at $3.00 per night. Mail your application now to secure your first choice of desired accommodations. All requests for reservations must give a definite date and estimated hour of arrival, and also probable date of departure.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

For a list of the headquarters of each participating society and section, see page 197, *Science*, 21 July. The Hilton is the AAAS headquarters hotel.

Rates for Rooms with Bath*

Hotel	Single for one	Double for one	Double for two	Twin Beds for one	Twin Beds for two	Studio Twins	Suites
Hilton	$8.50	$10.00	$14.00		$14.00	$15.00	$27.00 to $55.50
Brown Palace	8.00	9.00	13.00	$10.00	15.00		24.00 to 65.00
Cosmopolitan	8.50	9.00	13.00	10.00	14.00		25.00 to 60.00
Shirley Savoy		7.50	10.00	9.00	12.00		25.00 to 40.00

* All rooms are subject to a 2% Colorado State sales tax.

THIS IS YOUR HOUSING RESERVATION COUPON

AAAS Housing Bureau
225 West Colfax Avenue
Denver 2, Colorado

Date of Application .....

Please reserve the following accommodations for the 128th Meeting of the AAAS in Denver, 26–31 December 1961:

TYPE OF ACCOMMODATION DESIRED

Single Room ..... Double-Bedded Room ..... Twin-Bedded Room ..... **Studio Twins** .....

Suite ..... Desired Rate ..... Maximum Rate .....

Number in party ..... Sharing this room will be: .....

(Attach list if this space is insufficient. The name and address of each person, including yourself, must be listed.)

.....

.....

First Choice Hotel ..... **Second Choice Hotel** ..... **Third Choice Hotel** .....

DATE OF ARRIVAL ..... DEPARTURE DATE .....
(These must be indicated—add approximate hour, A.M. or P.M.)

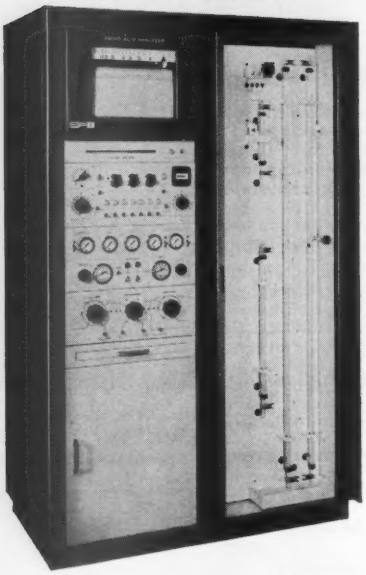
NAME .....
(Individual requesting reservation) **(Please print or type)**

ADDRESS .....
(Street) **(City and Zone)** **(State)**

Mail this now to the Housing Bureau. **Rooms will be assigned and confirmed in order of receipt of reservation.**

PHOENIX Amino Acid Analyzers

MODEL K-8000



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- **Tissue extracts**
- **Hydroponic solutions**
- **Foods**
- **Culture media**
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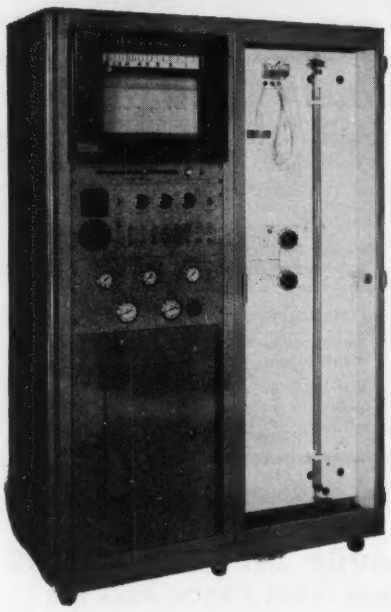
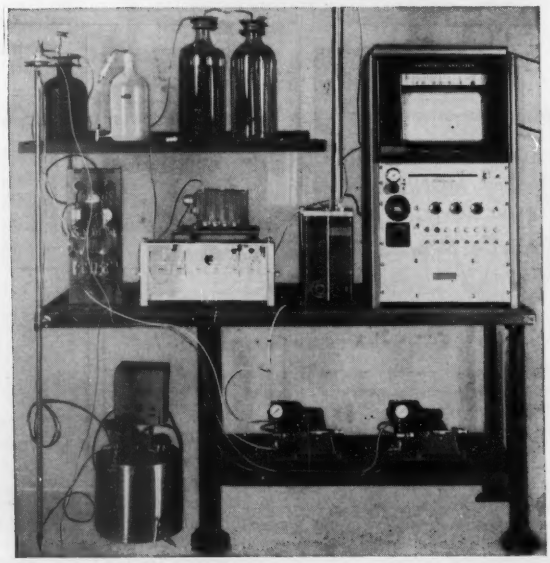


Phoenix offers a complete line of components, replacement parts, and accessories for use with the Spackman-Stein-Moore Amino Acid Analyzer System, as described in Analytical Chemistry 30, No. 7, pages 1190–1206 (1958) and the Variable Gradient Analyzer System as described by Dr. Karl A. Piez and Louise Morris in the November 1960 issue of Analytical Biochemistry. For complete details, write Phoenix Precision Instrument Company, 3803–05 N. 5th Street, Dept. K, Philadelphia 40, Penna.

MODEL VG-6000-B

COMPONENTS ALSO AVAILABLE SEPARATELY FOR BENCH-TYPE ARRANGEMENT, AS SHOWN BELOW



MODEL 5400

RECORDING FLOW-PHOTOMETER

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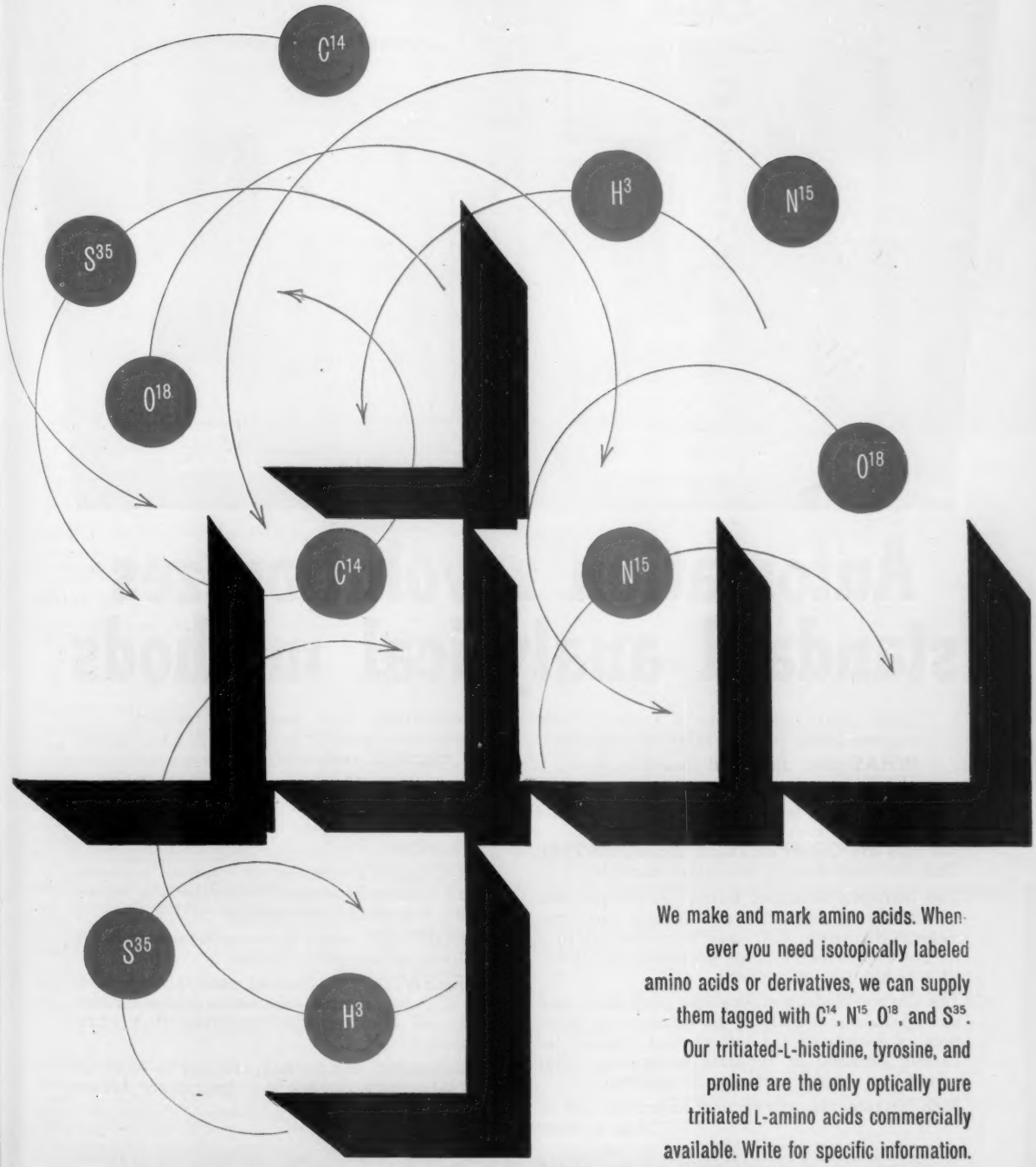

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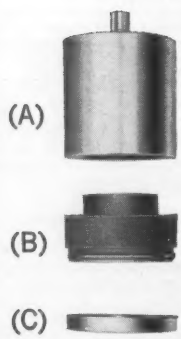
New *Tracerlab* FLOW COUNTERS feature

Mono-Mol (<125 μg/cm²) Windows... Exceptional Plateau Characteristics... Plug-In Construction



Exploded view of the FD Series Flow Counter showing (A) Counter Shield (B) Plug-in Flow Counter (C) Snap-On Window.

The new Tracerlab FD Series Mono-Mol Window Flow Counters operate in a variety of counting modes with your choice of counting gas. Excellent plateau characteristics insure a constant counting rate. Mono-mol windows, the world's thinnest windows, permit passage of all but the weakest particles. Plug-in construction simplifies operation.

The basic counters are available in 1″ or 2″ models and both operate in the geiger region with standard Tracerlab G-1 gas, or in the proportional region with argon methane G-2 Gas, pure methane or natural gas.

Construction is all plastic to minimize background and cathodes are deposited stainless steel.

A glance at the operating specifications of the new Tracerlab Flow Counters will show you why these low cost, long lasting, extremely efficient units belong in your sample counting system.

SPECIFICATIONS THIN WINDOW FLOW COUNTERS

Model No.	Operating Mode	Gas	Required System Sensitivity	Operating Voltage	Background	Plateau	
						Length	Slope over entire range
FD-1*	Geiger	G-1	.25V	1450V ± 150	<12 c.p.m.	300V	<2%/100V
FD-2**	Geiger	G-1	.25V	1450V ± 150	<30 c.p.m.	300V	<2%
FD-1	Prop.	G-2	α 10 mv	2200V ± 500	α < 6 c.p.h.	1000V	<2%
			β 1 mv	2300V ± 200	β <12 c.p.m.	400V	<2%
FD-1	Prop.	Pure Methane	α 10 mv	3500V ± 500	α < 6 c.p.h.	1000V	<1%
			β 10 mv	4500V ± 500	β <12 c.p.m.	1000V	<1%
FD-1	Prop.	Natural Gas	α 10 mv	4000V ± 500	α < 6 c.p.h.	1000V	<2%
			β 10 mv	4700V ± 300	β <12 c.p.m.	400V	<2%
FD-2	Prop.	G-2	α 10 mv	2200V ± 500	α <12 c.p.h.	1000V	<2%
			β 1 mv	2300V ± 200	β <30 c.p.m.	400V	<2%
FD-2	Prop.	Pure Methane	α 10 mv	3000V ± 500	α <12 c.p.h.	1000V	<1%
			β 10 mv	4500V ± 500	β <30 c.p.m.	1000V	<1%
FD-2	Prop.	Natural Gas	α 10 mv	4000V ± 500	α <12 c.p.h.	1000V	<2%
			β 10 mv	4700V ± 300	β <30 c.p.m.	600V	<2%

*FD-1 1″ Super/thin Window Flow Counter **FD-2 2″ Super/thin Window Flow Counter

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Tracerlab Kelsey

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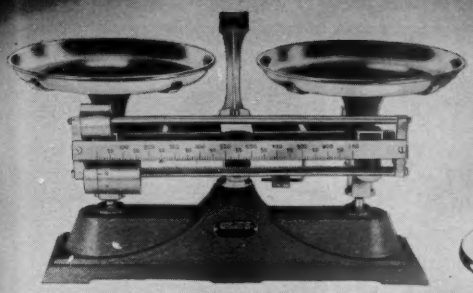
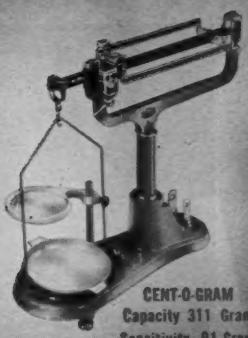


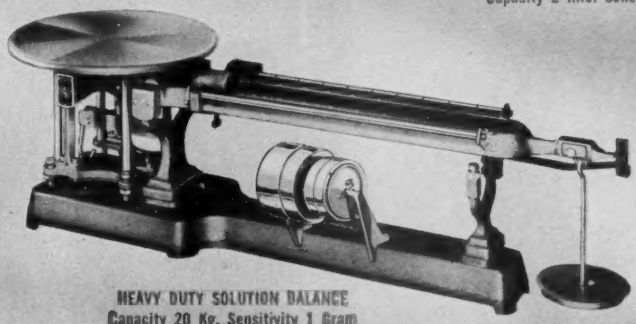
INDUSTRIAL BALANCE
Capacity 5 Kg. Sensitivity 0.5 Gram

STO-A-WEIGH
WEIGHT SET

HARVARD TRIP BALANCE
Capacity 2 Kilo. Sensitivity 0.1 Gram

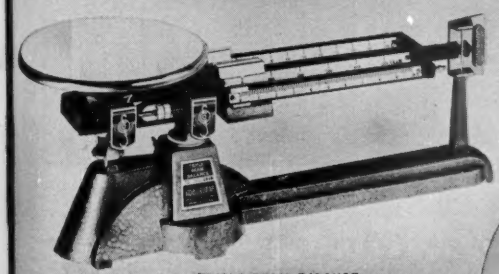


CENT-O-GRAM
Capacity 311 Gram
Sensitivity .01 Gram



HEAVY DUTY SOLUTION BALANCE
Capacity 20 Kg. Sensitivity 1 Gram

DIRECT READING
MOISTURE DETERMINATION
BALANCE
Capacity 10 Gram
Sensitivity .01 Gram—0.1%



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F & M's
MODEL 609
GAS
CHROMATOGRAPH

OFFERS PARTS-PER-BILLION SENSITIVITY FOR RELIABLE CHEMICAL ANALYSIS

If you require ultra-sensitivity in your analyses of organic compounds, consider the advantages of F & M's Model 609 Gas Chromatograph with flame ionization detector. It offers parts-per-billion sensitivity. (Typical sensitivity for a light hydrocarbon is 5 to 50 ppb.) Yet, neither water nor air gives a signal. For these reasons, the Model 609 is ideal for reliable analyses of (1) trace components in complex mixtures and (2) trace organic materials in air or aqueous solutions.

In analyses of wide boiling mixtures, the Model 609 can be operated with programmed temperatures up to 300°C (with a choice of 18 linear heating rates from 0.23 to 35°C/min). Or, the instrument can be operated isothermally.

Packed analytical columns with lengths up to 50 feet can be used with the Model 609. Also, adapters are available for capillary columns. Other features of this instrument include (1) attenuation from 1 to 1,000,000; (2) line-operated electrometer; (3) independent heating of column, detector, and injection port.

Write today for further information about this versatile, reliable gas chromatograph.

See the Model 609 and other F & M gas chromatographic instruments on display at the *Eastern Analytical Symposium,* New York City, November 15-17 (Booth 45).

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NIKON model 6 OPTICAL COMPARATOR

for fast, accurate evaluation of ultracentrifuge photo plates

A major pharmaceutical manufacturer recently investigated the use of a Nikon 6 Optical Comparator for measuring and analyzing ultracentrifuge photo plates. The performance was so impressive, the unit was immediately purchased and added to the company's instrumentation facilities. The news travelled.

Within less than a month, a Nikon 6 Comparator was acquired by a large hospital, and shortly thereafter, by several other hospitals and by a food research laboratory. The Comparator, in each instance, demonstrated a marked superiority over equipment previously used—greater speed and convenience, and greater accuracy.

The Nikon 6 Optical Comparator is essentially a macro projector with a magnification range from 10x to 100x—extendable to 500x. Any object, thing, substance, specimen, photo plate or slide placed upon the stage, appears on its 12" screen as a sharp, bright, magnified image, which can be observed by many people simultaneously —studied, evaluated and precisely measured. And all of this can be done comfortably in a normally lit room. The Model 6 Comparator is provided with surface as well as sub-stage illumination.

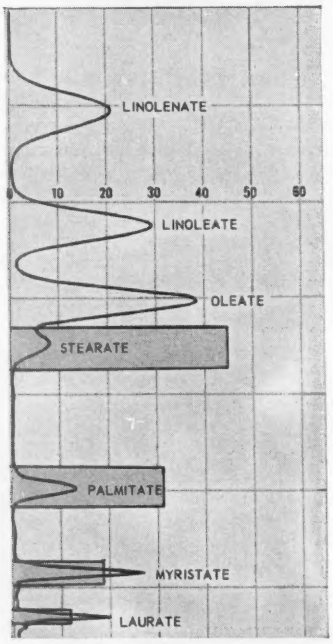
New laboratory applications for the Nikon 6 Comparator are being constantly reported. In addition to the analysis of ultracentrifuge data, its use has been extended to many phases of chromatography, evaluating fringe patterns and reading electrophoresis photo plates and cells.

You may have an inspection or measurement problem which lends itself to the unique capabilities of the Nikon 6 Optical Comparator. Why not tell us about it. Write to Dept. S-10.

NIKON INC., INSTRUMENT DIVISION, 111 Fifth Ave., N. Y. 3, N. Y.

A NEW APPROACH

To Precise Measurement of Radioactivity In Gas Chromatography



Typical gas chromatogram trace showing mass peaks of fatty acid methyl esters. Superimposed on the mass trace, the bar graph indicates no radioactivity in any of the unsaturates.

The Packard Model 830 Tri-Carb® Gas Fraction Collector enables quantitative collection of individual organic components in a gas chromatographic effluent stream. Precise measurement of radioactivity in component peaks can be made after collection.

An 8″ diameter turntable holds up to 50 Tri-Carb Cartridges, each packed with silicone-coated scintillation crystals. Vapors leaving the gas chromatography mass detector pass through the heated gas injection nozzle of the collector and condense on the coated surfaces of the scintillation crystals. As the operator observes the beginning and completion of each peak on the mass detector trace, he actuates a control switch to change cartridges. Changing takes only a fraction of a second.

After sample collection, the cartridges are placed in positioning adapters in an Automatic Tri-Carb Liquid Scintillation Spectrometer for completely automatic counting. No sample preparation is necessary and up to 100 samples can be handled at one time.

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The Packard Model 830 Tri-Carb Collector is suitable for use with any gas chromatograph using a nondestructive mass detection system.

For information call your Packard Sales Engineer—or write for descriptive literature.

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PACKARD INSTRUMENT COMPANY, INC.

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TORSION MODEL DWL-3
Capacity: 200 grams
Weight-loading Dial: up to 9 grams by 1 gram increments
Fine Weighing Dial: 1 gram by .02 gram graduations
(Readability: .005 g)

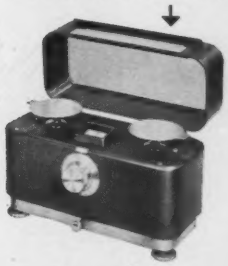
TORSION DWL-5
Capacity: 500 grams
Weight-loading Dial: up to 90 grams by 10 gram increments
Fine Weighing Dial: 10 grams by .1 gram graduations
(Readability: .02 g)

TORSION DWL-2
Capacity: 120 grams
Weight-loading Dial: up to 9 grams by 1 gram increments
Fine Weighing Dial: 1 gram by .01 gram graduations
(Readability: .002 g)

TORSION DWL2-1
Specifications are same as the DWL-2 except that this model has scoop for seeds or other bulky material

TORSION DLT5
Capacity: 500 grams
Dial graduated 10 grams by .1 gram graduations
Readability of Dial: .02 grams

TORSION DLT2
Capacity: 120 grams
Dial graduated 1 gram by .01 gram graduations
Readability of Dial: 2 mg



TORSION DLT2-1
Same specifications as DLT2 but has scoop for seeds or other bulky material

TORSION DRx
Capacity: 120 grams
Dial graduated 15 grains by ⅛ grain graduations and 1 gram by .01 gram graduations
Readability of Dial: ¼ dial division

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20 October 1961, Volume 134, Number 3486

SCIENCE

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The Other Fellows' Ball Park

There is an old saying that when one goes to play ball in the other fellows' ball park, it is incumbent upon him to learn the others' ground rules. There is no use protesting about these rules or asking that they be altered. The reasonable course is to find out what they are and proceed accordingly.

In the same way, the scientist entering into the affairs of government, and into the political arena, has the duty—if he is to be fully effective—to find out how men in this arena actually function. It is not sufficient for him to criticize their methods, and it is fatal if he take the point of view that he is now in a section of society which is governed by rules less ethical or less advanced than his own. We live under a democratic system. An essential feature of this system is the means by which men acquire and maintain political position and authority. These means involve a thorough understanding of human nature and of mass reactions. Many men in political life are masters of this art. And in the large majority they are also devoted to the welfare of their country. As a result we have effective working of the democratic system as far as efficiency in government is possible. The democratic system creaks at its joints, it wastes time and money, it bases its decisions more on subtle influences than on rational logic, and it often irritates those who are accustomed to more orderly and systematized functioning. But it just happens that the democratic system with all its faults is the best system of government ever devised by the mind of man. Scientists today are privileged to participate in this whole affair to an extent never before true in this country, and it is certainly incumbent upon them to understand and indeed to sympathize with the local ground rules which govern the ball park in which they are now exercising important influence.

I have seen great damage done to the whole scientific community by the eminent scientist who, appearing before a congressional committee, made evident his general contempt for the individuals before whom he appeared, and who talked to them as he would to a group of school boys. Fortunately, in the years since the War, scientists have matured in this regard and this does not now occur.

We need now to go beyond this in our thinking. As scientists and engineers we nevertheless regard with admiration and respect the subtle functioning of a medical man in a difficult case, not relying upon the science which underlies his art, but relying upon the art itself, who rescues a patient from an obscure source of distress. We admire and respect also the artist who, knowing very little about the physics of color or of light reflections, produces a work of art that stirs emotions or revives long-forgotten memories. In the same way we need to learn to respect, in fact to admire, those individuals who are masters of the art of operating in the confused arena of the American political scene, especially when this subtle undefinable skill is joined with a broad altruism. In fact, if scientists are to have their full influence for the good of the country in the days to come, many of them will indeed need to learn to practice this difficult art.—VANNEVAR BUSH, *Massachusetts Institute of Technology*. (Excerpt from an address read at the 15th National Congress on the Administration of Research, San Juan, Puerto Rico, 10 Oct. 1961)

20 October 1961, Volume 134, Number 3486 SCIENCE

INSTRUMENTS AND TECHNIQUES

New Frontiers of Astronomical Technology

Technological developments challenge the astronomer, both from the ground and in space.

Aden Baker Meinel

The principal tool of the astronomer, the telescope, is basically an instrument designed to gather the light of stars and other celestial objects and focus it with precision. Most celestial objects are intrinsically very luminous objects, but they appear faint because of their great distances from us. The brightest star, Sirius, with an intrinsic luminosity 28 times that of the sun, is approximately 10,000 million (10^{10}) times apparently fainter than the sun. The faintest object detected with the 200-inch telescope, of 23rd magnitude, is another 10,000 million (10^{10}) times fainter. The faintness and small angular size of celestial objects (other than the sun and moon) set the unusual characteristics of astronomical instrumentation and research.

Very little astronomical work is done today by looking through the telescope, except as this is incidental to the setting of the telescope on the desired region of the sky. In recent decades the astronomer has worked principally with the photographic process to determine the positions, motions, and brightnesses of celestial objects. The photographic process still represents a method of information retrieval unrivaled for pictorial display, as is evidenced by the photographs from the 120-inch Lick and the 200-inch Palomar telescopes, shown in Figs. 1–4. The most efficient emulsions, however, utilize only 1 percent of the incident light. In recent years certain astronomical observations, particularly those of the brightness of stars, have been made with greater precision and light efficiency by using photomultiplier cells such as the RCA 1P21 and EMI.

The principal auxiliary instruments currently used by astronomers are the direct photography plateholder, the photoelectric photometer, and the spectrograph. A spectrograph can reveal many interesting properties of a star, such as temperature, mass, chemical composition, atmospheric structure, multiplicity, motion toward or away from the observer, and, indirectly but effectively, the absolute luminosity and hence the distance and even the age of the star. Other kinds of special equipment have been devised from time to time to measure special properties such as polarization of starlight and magnetic fields of stars.

Since the turn of the century the astronomer has pushed the telescope close to its maximum useful size. Four telescopes with aperture sizes of 100 inches or more have been successfully built. The 100-inch on Mt. Wilson was completed in 1919 and, in the hands of Hubble and Baade, did much to revolutionize astronomy. This was followed by the 200-inch on Mt. Palomar, completed in 1947, and by the 120-inch on Mt. Hamilton, in 1959. The fourth, of 104-inch aperture, is now being placed in operation in Russia. A giant of 240-inch aperture is reported under design by the Institute of Optics in Leningrad.

Each new and larger telescope costs much in return for a relatively small gain in distance reached and in new knowledge. In line with the times, we must look for a "new frontier" to explore and develop (*1*). Thus, we can look for new methods enabling us to make better use of the starlight that is collected by our terrestrial telescopes, and we can also look to the new field, so challenging to astronomers, opened up by the development of aerospace technologies.

Atmospheric Effects

Telescopes have always operated under the handicap of an atmosphere that is opaque to most electromagnetic radiation, and that is constantly in motion. The various turbulences always present in the atmosphere are accompanied by thermal differences that make it impossible to focus a telescope to its theoretical angular resolution. In addition, the sky background is far from dark. Even in the absence of moonlight and far from the light of cities one can easily read the large-headline type of a newspaper by the light of the night sky. From the surface of the earth the stars are seen projected upon this faintly luminous background. It is this diffuse light of the night sky, in fact, that sets the limit in faintness to which a telescope can reach.

The light of the night sky is from several sources, both terrestrial and extraterrestrial. The lower atmosphere of the earth scatters starlight (7 percent). The upper atmosphere contributes the airglow, or permanent aurora, as it is

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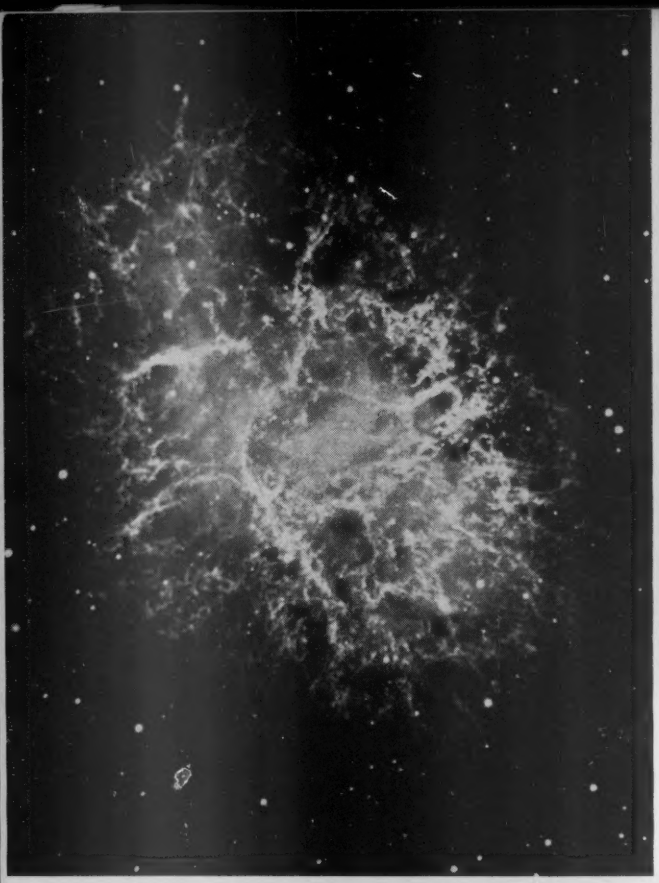
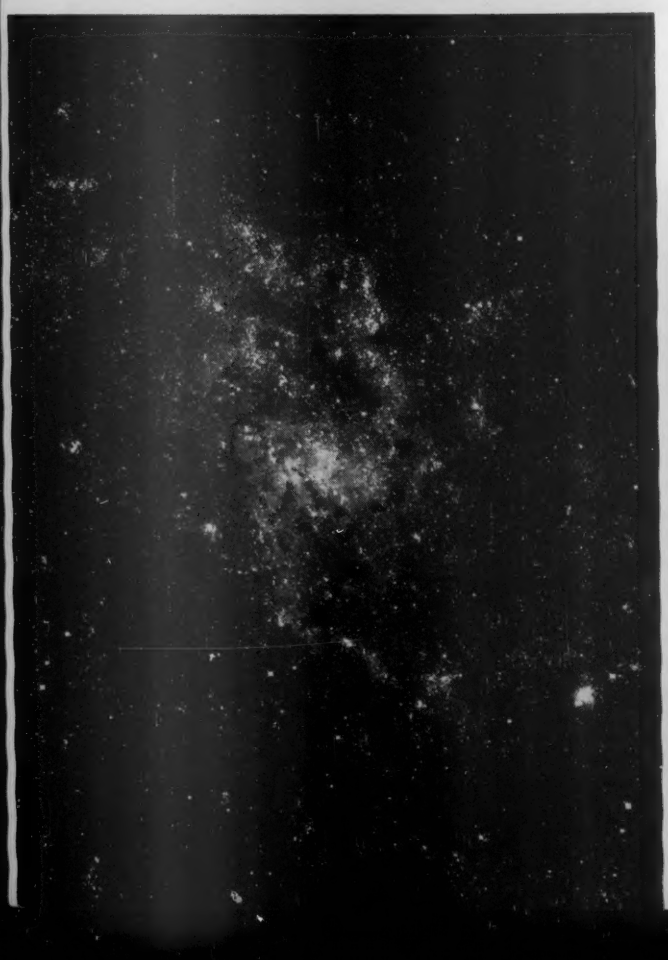


Fig. 1 (top left). Crab Nebula, M1, in red light, taken with the Lick Observatory 120-inch telescope, 3 November 1959. Exposure, 30 minutes; 103aE2 + R61 plate and filter. [N. U. Mayall] Fig. 2 (top right). Region in Corona Borealis taken with the Palomar 200-inch telescope. Each of the diffuse or elongated objects is a separate galaxy. Exposure, 30 minutes; 103a-O plate. Fig. 3 (bottom left). Galaxy M33 in Triangulum, in blue light, taken with the Lick Observatory 120-inch telescope. 17 September 1960. Exposure, 30 minutes; 103a-O plate. [S. Vasilevskis] Fig. 4 (bottom right). Region at center left of Fig. 3, showing resolution of the galaxy into stellar images. The small images are of approximately ¾ second of arc diameter.



sometimes called (40 percent). Both of these components will be eliminated in light viewed through a telescope located more than 500 miles above the earth. The remaining light comes from interplanetary, stellar, and interstellar sources. The interplanetary light comes from the scattering of sunlight by meteoric dust and gas in the solar system; it is known as zodiacal light (average, 20 percent). It usually appears brightest in late twilight or early dawn, as a hazy band of light stretching outward from the sun along the ecliptic. The stellar light (20 percent) comes from faint stars and galaxies that are not resolved by the telescope as individual stars, since only the relatively infrequent high-luminosity stars can be seen separately as stars, even those in our own Galaxy. The last component, of interstellar origin, arises from the scattering of starlight by interstellar dust and gas (13 percent). Interplanetary, stellar, and interstellar light sources will still limit the operation of a telescope at orbital altitude.

The total brightness of the night sky in its darkest regions, as seen through a large telescope, is approximately equal to a brightness of one 20th-magnitude star per square second of arc. It is obvious, therefore, that we cannot tolerate many square seconds of arc in our detector when we wish to observe a 23rd-magnitude star. When a 23rd-magnitude star is observed with one of the very large telescopes, the detector records approximately one photon count per second. Since the error of an observation consisting of N events is equal to $N^{\frac{1}{2}}$, one must collect photons for 167 minutes to measure the brightness of such a star to an accuracy of 1 percent. With so few quanta from celestial sources, the astronomer has four means of making gains: (i) increase the size of the telescope mirror; (ii) increase the efficiency of the detector; (iii) decrease the aperture (sky noise) at the detector; and (iv) place the telescope above the atmosphere.

The first alternative—building larger telescopes—has been considered. While it is within the scope of present-day technology to build a 400-inch telescope, the cost would be in the vicinity of $40 million and the benefits are doubtful because of the limitations imposed by atmospheric "seeing," unless a site with exceptionally fine seeing could be found.

The effects of the terrestrial atmosphere on an incoming beam of starlight in the wavelength region of light transmitted by the atmosphere are twofold: (i) time fluctuations in the intensity of the wave front arriving at a given point at the telescope aperture, and (ii) time fluctuations in the direction of arrival of the wave front. The first effect is called scintillation and is readily seen with the unaided eye as twinkling. The second effect is usually referred to as "seeing," since it affects the ability of a telescope, especially a large one, to focus sharply. Both effects are caused by the presence of irregularities in the index of refraction of the atmosphere.

Research has now established that

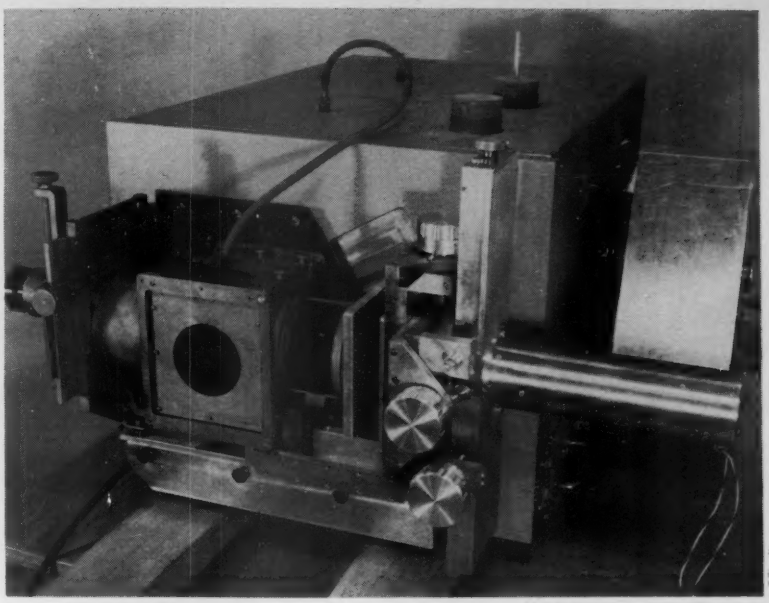


Fig. 5. Image orthicon camera developed by Livingston at Kitt Peak National Observatory. The orthicon is located inside a refrigerated box, with various test and operating auxiliaries on the front face.

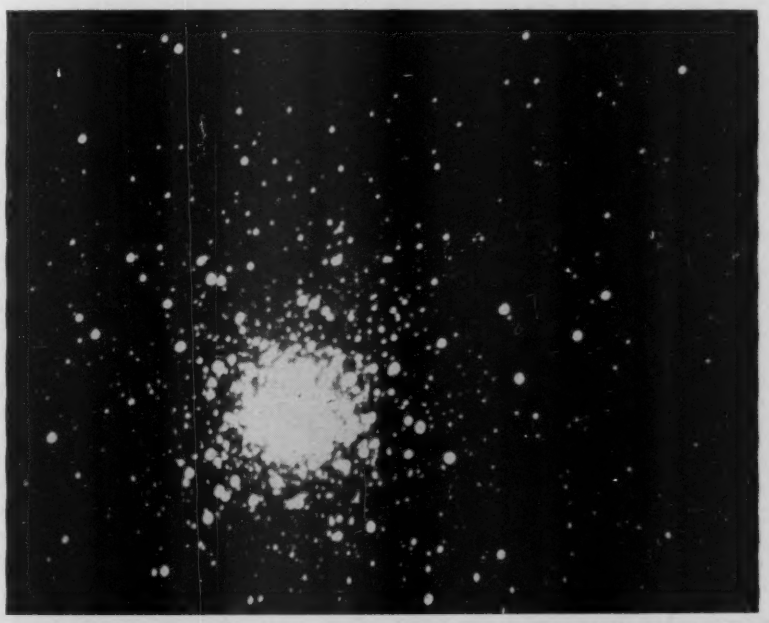


Fig. 6. Globular star cluster M3 in yellow light, taken at Kitt Peak 19 March 1961 with a GL-7629 image orthicon. Exposure time, 8.5 sec. [Livingston]

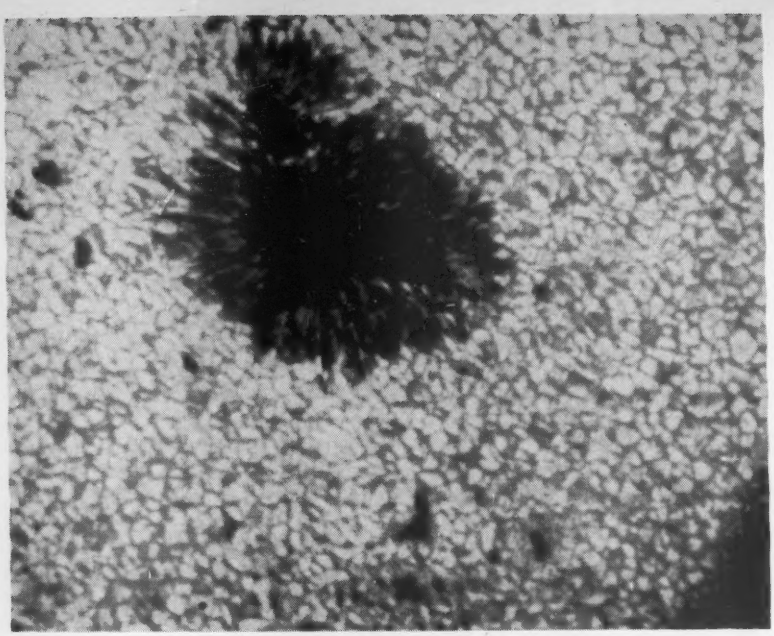


Fig. 7. The sun, taken with the Stratoscope I system from an altitude of 80,000 feet; the theoretical resolution of the telescope was attained.

scintillation effects arise high in the atmosphere, while the major seeing effects arise close to the ground. To minimize these seeing effects, telescopes are now located, at no small inconvenience, on the summits of mountains in relatively undisturbed air. In the best sites, the average seeing-image diameter, for a large telescope, is between 1 and 2 seconds of arc. Upon rare occasions the minimum seeing-image diameter may approach 0.3 second of arc; however, this is still much below the theoretical resolving power of a large instrument. As a consequence, a very large telescope can produce only a larger picture of the same blurred celestial objects. Under these conditions the telescope only gathers more quanta per unit time, and the gain in signal to noise (N^2/N) is proportional to the linear aperture of the telescope. Since the cost varies nearly as the 2.8th power of the aperture, the cost in terms of information gain is very high.

Detector Efficiencies

The second possible means of making gains is that of increasing efficiency in the detection of photons. The photographic process has for many years been the chief detection method in astronomy. The process has a wide dynamic range, but relatively low fidelity as far as intensity registration is concerned. The quantum efficiency of a photographic emulsion is low, ranging from 0.1 to 1 percent for the optimum use of the fastest emulsions. The dynamic range and information retrieval of the photographic emulsion are remarkable. One photograph may record star images over a range of 20 magnitudes (10^8) and also record a million information elements per square centimeter. Information densities up to five million per square millimeter are possible under laboratory conditions.

Improvement in the quantum efficiency of a detector thus promises a greater gain than does an increase in the size of the telescope, for the same expenditure. There is little basis for hoping that there will be large improvements in the photographic process itself, since individual silver grains are quite good detectors. The quantum efficiency required for a single grain to be developable, in terms of absorbed photons, is 25 percent; however, a single grain has a low absorption cross section. Moreover, one developed grain does not provide a detectable quantity. Only when groups of 20 to 100 grains are developed does one find a star as an entity on the background of random developed "noise" produced by fog-grain clumpiness.

In recent years much effort has been devoted to the utilization of the high quantum efficiencies (approximately 20 percent) of the photoelectric detector. The photomultiplier is a commercially available device of high efficiency that has been widely employed in astronomy and particle physics. The internal amplification of this device (10^7) produces a measurable pulse for each photoelectron emitted from the cathode. The cathode will occasionally eject a thermal electron spontaneously as a consequence of the low work function of the cesium-compound emitting surface. These thermal electrons produce what is called the dark current, which adds a noise background to the signal. A good photomultipler at room temperature will have a dark current of 10 to 20 electrons per second per square centimeter of photo-cathode surface. Because the dark-current emission of electrons is temperature-dependent, the astronomical use of photomultipliers is almost always at low temperatures. At Dry-Ice temperature (−80°C) a good photomultiplier will have a dark current of 0.1 to 0.5 electron per second per square centimeter.

The photomultiplier is an excellent detector for the observation of a single object at a time. The output current is accurately linear over a wide range of intensities; hence, brightness can be measured with high precision. In practice, the photoelectric photometer attached to a telescope isolates a single small region of the sky, containing the object, by means of a small diaphragm. In order to reduce the noise background of the sky in observing a faint object, this diaphragm is kept as small as the stellar seeing disk and guiding accuracy of the telescope will permit. Diaphragms as small as 0.1 millimeter have been used, but with brighter objects it is convenient to use a diaphragm as large as 5 millimeters in diameter.

The photomultiplier, while very sensitive, has a slow information-recovery rate. At the faint limit of the 200-inch telescope, Baum (of Mt. Wilson and Palomar Observatories) has spent an entire night measuring a 23rd-magnitude star in three broad wavelength bands. To use a single photomultiplier to successively examine more than a few hundred information elements to that faintness is, therefore, out of the question. If, for example, the photomultiplier is 100 times more efficient than a photographic emulsion, then one could retrieve information for 100 picture elements in the time required for a photograph. In other words, one could not effectively exceed the information-re-

covery capability of a photographic emulsion with a scanning photomultiplier if many elements must be scanned. Nevertheless, when the ultimate in accuracy is desired, a photomultiplier is often used, even if it is somewhat slower than a photographic plate. On the other hand, if one could use the sensitivity of the photo-cathode in an imaging device, much gain would result.

Electronic Imaging Devices

The electronic image tube is currently under intense development as the first device to challenge seriously the information-retrieval properties of the photographic emulsion. The simplest form uses an electrostatic (or magnetic) lens to re-image accelerated photoelectrons upon a recording surface. Some of the earliest image tubes have used a phosphor as the recording screen, which in turn is photographed. This device was used by Krassovsky (of the U.S.S.R.) in 1950 to observe the infrared air-glow spectrum, a task impossible with the photographic emulsion because of its very low sensitivity in the 10,000-angstrom region. In recent years Hall and Ford (of Lowell Observatory) have used similar techniques with success; however, the phosphor is an inefficient intermediate medium.

Lallemande (Observatorie de Paris), Hiltner (Yerkes Observatory), and Kron (Lick Observatory) have in recent years successfully eliminated the phosphor by imaging the photoelectrons directly upon the photographic emulsion. The reduction in contamination of the photo-cathode by the photographic plate was one of the difficult problems faced in this technique; however, the device is now in a semioperational state. Recent research at Lick Observatory with the Lallemande-type tube on the 120-inch telescope has yielded new observational results and a net speed gain of about 30 times that of a photographic plate. A modification by Hall (Lowell Observatory) and by Hiltner (Yerkes Observatory), using thin film windows of mica or aluminum oxide to lessen the contamination, has shown encouraging results. In these tubes the photographic plate is placed in contact with the thin window to minimize electron scattering by the window.

The image orthicon is a different approach to the development of a more sensitive image tube, and this technique has been pioneered by Livingston (Kitt Peak National Observatory), DeWitt (Vanderbilt University), and Spalding (General Engineering Laboratories, Schenectady) (Fig. 5). Their developments are based upon the high sensitivity and integrating properties of certain new types of image orthicons. The promise of this type of image tube is shown in the short-exposure photograph of a star cluster (Fig. 6) taken at Kitt Peak by Livingston. The use of these scanning systems is especially attractive for future applications, since electronic processing and information retrieval by telemetry are possible.

A vast military technology has developed for infrared detection (1 to 20 μ), which has not as yet been fully applied to astronomy. Strong (Johns Hopkins University) and Kuiper (University of Arizona) have pioneered in the astronomical application of infrared techniques, and Sinton (Lowell Observatory) has extended this work, but much remains to be explored. The principal reason why infrared techniques have not been used more in astronomy is that the atmospheric transmission is highly variable in these spectral regions and detectors are inefficient to the extent that only the most luminous objects are within reach of a large telescope.

Stratospheric Telescopes

The third possible means of improving the operating efficiency and research potential of a telescope is to improve seeing conditions, thus decreasing the seeing image of the celestial object and, in effect, increasing the resolution of the telescope. Much effort was expended in selecting the location of the Palomar and Kitt Peak observatories to find a site with the best possible seeing conditions. It does not appear that much can be gained in this respect in locating future telescopes as long as the terrestrial atmosphere is involved, although an exceptional site might provide conditions twice as good as those at existing sites. Only when one can place his telescope above the atmosphere does the theoretical resolving power of a telescope become attainable.

Balloon-borne telescopes offer the possibility of a major increase in the resolution of a telescope. At altitudes of approximately 80,000 feet there is essentially no seeing disturbance, even from direct sunlight on the telescope. While visual observations have been made from balloons by Dolfuss (Observatorie de Paris), the first successful demonstration of high-resolution photography was made with the 12-inch Stratoscope I system by Schwarzschild (Princeton University). This unmanned photographic telescope has taken superb direct photographs of the sun, achieving the full theoretical resolution of the telescope (Fig. 7). The same balloon-borne stabilized platform has been flown by Newkirk (High Altitude Observatory), with a coronagraph to study the outer corona.

At the present time the 36-inch Stratoscope II system, also developed by Schwarzschild, is nearing completion (Fig. 8). This instrument is large enough to permit observation of planets, stars, and nebulas, and it is designed to

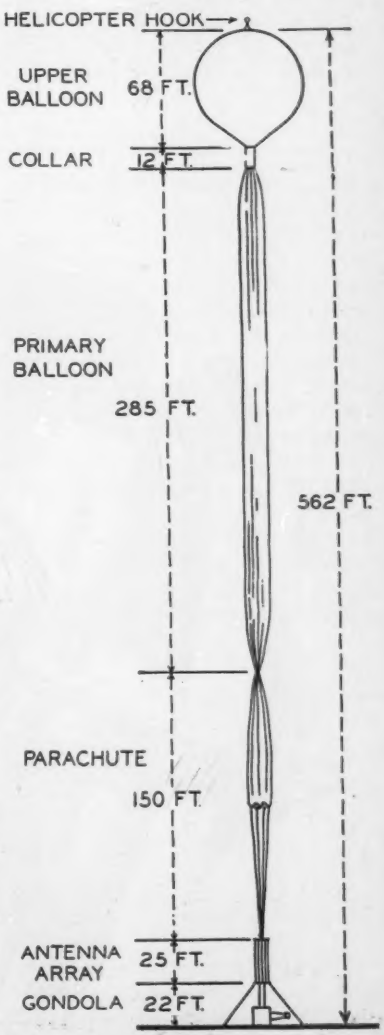


Fig. 8. The Stratoscope II system, which will carry a 36-in. telescope to 80,000 feet for night observations.

yield a guidance accuracy of 0.1 second of arc over extended periods. The size and complexity of this instrument are such, however, that a sizable support operation is required for launching and recovering the telescope. It is to be hoped that, as balloon-borne telescopes are developed, a permanent facility will be established so that astronomers can work with such instruments without the prodigious effort in systems development now required of individual astronomers.

Balloon astronomy, like the rocket astronomy of the last decade, can be viewed as an interim step, preliminary to the establishment of more permanent observing stations above the atmosphere. From a vertical rocket probe one can glimpse the sky for only a few minutes on a flight, and at present, the number of such flights is limited to three to six per year. In the case of balloons, one can expect observation time of a few hours per flight in three to six flights per year. The cost per hour of observing is indeed high, but the return is also high, since the results of these operations will point the direction of research with subsequent satellite telescopes.

Space Astronomy

The use of rockets in the last decade has led to the development of instruments to observe the sun spectrographically from the 3000-angstrom atmospheric cutoff into the x-ray region. The beautiful far-ultraviolet spectra and Lyman-α photographs of the solar disk obtained by Tousey and his group (Naval Research Laboratory) are well known. The short observation time available on these flights has led to major advances in instrument technology. The development of the successful Aerobee pointing control by the Upper Air Laboratory at the University of Colorado, and the subsequent evolution of stabilized pointing systems, made it possible to use the entire period of flight above the atmosphere for observation. The parallel development of spectrometers, image-forming spectrometers, special detectors, and filters has progressed rapidly to a point where it is now possible to observe stars and nebulas. In a recent series of flights by Boggess (NASA) in 1960, observations of stars were made, for the first time, with multicolor broad-spectral-region detectors. A subsequent flight by Stecher and Milligan (NASA), on 22 November 1960, with spectrometers designed by the University of Rochester, yielded for the first time stellar spectral energy distributions below 3000 angstroms. The photograph of the spectrometer used on this flight (Fig. 9) illustrates the design problem posed by the weight and space limitations of rocket astronomy.

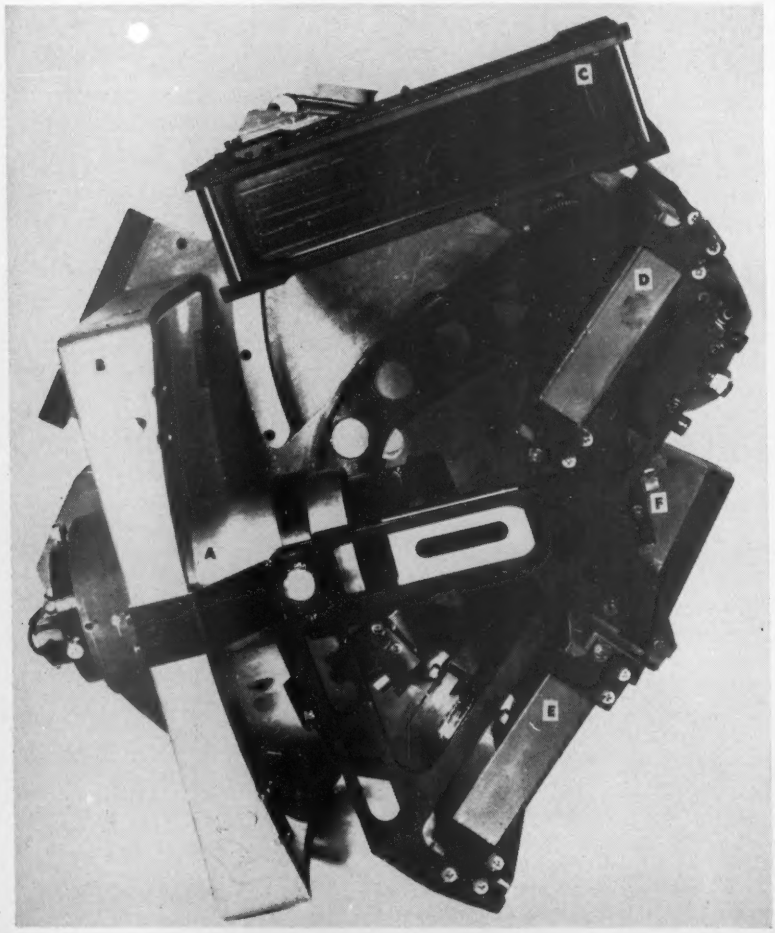


Fig. 9. The NASA–University of Rochester objective grating spectrometer for use in an Aerobee rocket. *A*, photocell; *B*, paraboloid; *C*, sky baffle; *D* and *E*, gratings; *F*, secondary.

The initiation of the Orbiting Astronomical Observatories (OAO) program by NASA now gives ground for hope that the astronomer will soon have telescopes of considerable size in orbit, providing extended periods of observation. The most obvious gain to be had from a space telescope is, of course, accessibility to the ultraviolet. The short-wavelength region is of great interest to the astrophysicist. In fact, the absorption cross sections become so large that it appears that even the dilute interstellar atomic hydrogen must certainly be opaque, over stellar distances, to radiations of wavelength shorter than 912 angstroms. In the infrared one expects only very weak interstellar absorption because of the presumed scarcity of molecules. If detector technology permits, the study of stars and of the interstellar medium in the infrared may bring surprising results.

A less obvious advantage—one that cannot be realized without further technological development—is greater resolving power. An orbital telescope can work at the theoretical resolving power of the optical system, since no seeing disturbance is present. Nidey and I (Kitt Peak National Observatory) have made system studies for high-resolution orbital telescopes. Given sufficient guiding accuracy, one could use diaphragms of very small angular size and increase the star-to-sky signal by many magnitudes.

If television devices of sufficient information-handling capability become available, then high-resolution photographs of the planets and other celestial objects can be obtained. While we do not now know of many crucial astrophysical problems that depend primarily upon higher angular resolution for their solution, the attainment of this resolution may of itself open new research fields. Even satellite observations in the visual region may prove attractive, in conjunction with observations in the other spectral regions. This possibility exists because an orbital telescope would enable the astronomer to plan and make a special observation, such as an observation of time-variable phenomena, at a predetermined time or for long periods of time, since neither weather nor considerations of daylight would interfere. Once per revolution of an OAO telescope a star will be occulted for 45 minutes, but as second-generation telescopes are developed, especially if they are placed in high-altitude orbits, observations of most celestial objects will be uninterrupted.

Space-Telescope Problems

The principal problem that must be solved if space telescopes are to be effective is that of information retrieval. That telemetry will be exclusively employed seems certain, since recovery of packages of data might well be prohibitively expensive and hazardous. A large number of information elements are contained in an astronomical photograph such as Fig. 3. A higher resolution, and consequently more information elements per square second of arc, will make the information retrieval problem even more formidable. The solution may lie in either of two directions. In the direct method, a slow-scan televison link and a high-sensitivity integrating image orthicon would be used. While Vidicon-type television tubes have been used in rocket and satellite instrumentation, they are relatively insensitive and could be used only for lunar and planetary work. "Ruggedized" image orthicons are under development for use in rockets and satellites. In the indirect method an intermediate recording surface, such as a photographic or xerographic film, would be used, and the picture would be subsequently transmitted by Vidicon or line-scan techniques.

In the design of satellite telescopes and instruments new boundary conditions are encountered. Two serious ones, aside from weight, are the low reflectivities of reflecting surfaces in the ultraviolet and the opacity of all transmission materials. The designer is, therefore, limited to the very few reflecting surfaces compatible with the design specifications. This requirement makes it mandatory that more sophisticated aspheric systems be utilized, in spite of attendant manufacturing problems. In space optics use may also be made of unconventional mirror materials. The lifetime of a space telescope is so short in comparison to that of a terrestrial telescope that optical stability of several months may be sufficient for the mirror materials.

The design of an orbiting telescope poses three major problems not encountered in designing terrestrial telescopes.

The launching g forces in particular are an example. During the launch into orbit a telescope may be subjected to vibration of approximately 5 to 10 g's over a frequency range of 5 to 1500 cycles per second. As a consequence, either the engineer must find a design that will preserve optical collimation or the astronomer will have to realign his optical systems after the telescope arrives in orbit. The lack of proper optical collimation could seriously degrade the performance of a space telescope.

The second major problem in the design of the space telescope is that produced by its thermal environment while in orbit. Sunlight will intermittently illuminate one side or the other of the space craft. This variable heating will produce a large and changing temperature gradient between the outer skin of the space craft and the telescope optical system. It will be necessary to keep the thermal gradient small in the optical system if high-resolution performance is to be obtained.

The third problem area, one common to all orbital instrumention, is that caused by prolonged operation of moving parts in the hypervacuum of space. The list of problems can easily be extended as one looks closer into the actual design of a space telescope.

A Lunar Observatory

There has been considerable speculation concerning the ultimate location of a space telescope. The inaccessibility of an orbiting telescope, for purposes of repair or for modification of the onboard experiments, would be a severe handicap. The establishment of a manned lunar base could considerably change this picture. If such a base should be established, we may be certain that a large lunar telescope would be constructed. While the erection of a lunar telescope would be an exceedingly expensive and challenging problem, the proposal is perhaps no more farfetched than the establishment of a great research facility at the South Pole, such as now exists, would have seemed a century ago (*1*).

Note

1. This article is contribution No. 11 from the Kitt Peak National Observatory.

Where Does Instrumentation Enter into Medicine?

Modern technology can help medicine meet growing demands through instrumentation and automation.

Duncan A. Holaday

The United States boasts of having the best medical care in the world. Yet this care is inadequate. A young house physician from one of our large metropolitan hospitals recently complained that he and two other doctors were forced to see and treat 180 patients in the course of a 3-hour clinic. This meant that the average patient had available to him only 3 minutes of a physician's time. The expanding demand for medical services that has resulted from Blue Cross and similar prepaid medical care plans cannot be met by our present facilities with present methods. To establish a diagnosis takes too long. To board and treat the hospitalized patient requires the time and attention of too many people. Coordination of the efforts of those responsible for the various aspects of medical care is too haphazard. The fact is that medical practice is where the manufacturing industry was at the beginning of the industrial revolution. All our work is piecework, and it is all done by hand.

It is true that medicine has special problems which set it apart from other industries. Each patient who presents himself for treatment differs from every other patient by virtue of differences in the progress of the disease and differences in age, nutritional status, reactivity to drugs, and responsiveness to therapy. Constant surveillance of the patient is necessary to detect changes in his condition. Each reaction to therapy, diet, or rest requires re-evaluation and possibly a change of regimen. The various aspects of medical care have become so complex that most of the physicians and technicians concerned with the patient are specialists, and many are subspecialists within their special fields of training—for example, the cardiopulmonary physiologist, the recovery-room nurse, and the intensive-care nurse.

Another important difference is that occasionally we must work with systems about whose mechanisms we have only a rudimentary knowledge. Until 39 years ago we had no idea what caused diabetes. Only in the past 12 years have we begun to appreciate the full significance of the complex hormonal balances which, day by day and hour by hour, efficiently regulate nutrition, cardiovascular homeostasis, and useful response to stress, disease, and inflammation. Even now our best men are scratching their heads over the most elementary aspects of the regulation of nervous activity, mental health, and emotional behavior. Growth itself, which is one of the most fundamental characteristics of living things, is still in large part a mystery.

Practices in Anesthesia

The special problems associated with the practice of medicine do not excuse or justify the archaic methods we employ for collecting data, processing and interpreting it, transmitting it, and translating it into action. Let me take a few examples from my own specialty, anesthesiology, to illustrate this.

The responsibilities of the anesthesiologist are complex and demanding. He must acquaint himself with the physical and mental status of the patient. Then, taking into consideration the surgical requirements of the operation to be performed, he must protect the patient from all painful and emotionally disturbing stimuli. He must prepare a relaxed field for the surgeon to operate in. He must, moreover, guard the patient from harmful reflexes, support his respiration and circulation, and return him to full consciousness and self-sufficiency as soon as possible after the operation is over.

What does he have to work with to accomplish all this? If he is fortunate he can devote 10 or 15 minutes the evening before the operation to examining the patient's chart and seeing the patient. The chart is a conglomeration of disjointed notes and reports, recorded in a nonuniform manner in as many as 10 or 20 different handwritings. If the patient has had a previous admission, his chart may consist of two or more volumes, all of which may not be readily available for examination. The drugs and agents the anesthetist uses to induce anesthesia and relaxation are, in the main, substances which disturb normal nervous balances, depress respiration, interfere with circulatory homeostasis, and cause temporary deviations of hormonal balance and metabolic activity.

His equipment consists of a blood-pressure cuff and stethoscope, a watch, and a few open-ended controls to regulate administration of his drugs. The latter are regulating devices that lack feedback; they include needle valves on the anesthesia machine, which control the flow of gases; the ether vaporizer (notorious for its failure to deliver vapor at a constant concentration), and infusion drip regulators.

To judge the adequacy of respiration he observes the movements of a rebreathing bag. To determine the circulatory status he feels and counts the pulse and measures the blood pressure, whenever it occurs to him to do so. To evaluate the depth of anesthesia he relies primarily on his eye to observe the activity of a few reflexes. This is the manner in which, I would judge, 95 percent of our anesthesias are being administered today.

Consequences

What are the consequences of this method of practice? At best, an occasional disaster or near disaster. The following are three actual case histories based on information recorded by the anesthesiologist.

Case 1. A young woman, 21 years old and weighing 131 pounds, with

The author is professor of surgery and head of the section of anesthesiology at the University of Chicago Clinics, Chicago, Ill. This article is adapted from an address before the New York section of the Instrument Society of America, 15 December 1958.

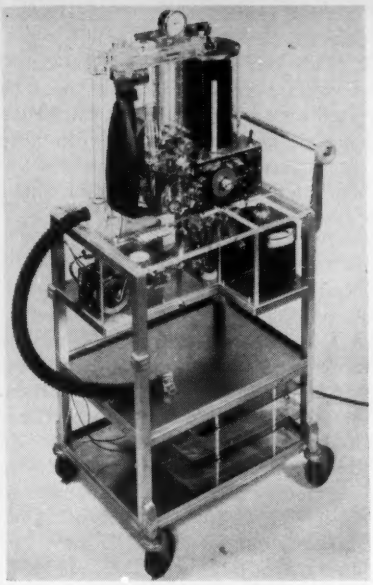


Fig. 1. The autoanestheton.

no known systemic disease except for chronic inflammation of the left middle ear, and with no known allergies, was prepared for mastoidectomy and tympanoplasty. Meperidine (60 mg) and scopolamine (0.4 mg) were administered intramuscularly 45 minutes before the induction of anesthesia. Anesthesia was begun with 125 milligrams of thiopental and was maintained with 3 liters of nitrous oxide and 1 liter of oxygen per minute and with intermittent intravenous dosage of thiopental and meperidine in small amounts. Succinylcholine, (40 mg) was given, and a rubber endotracheal tube, (size 40, French) was placed in the trachea 10 minutes after the induction of anesthesia. Five minutes later the flow of nitrous oxide was reduced to 2 liters per minute. The left mastoid region was infiltrated with 1-percent procaine containing eight drops of adrenalin solution. The skin was incised 25 minutes after anesthesia was begun. The blood pressure, as measured by auscultation, remained stable at 110 millimeters of mercury systolic, and 70 millimeters of mercury diastolic; the pulse was 80 beats per minute, and the rate of respiration fluctuated between 18 and 20 per minute. Four minutes after the skin incision was made the blood pressure was unobtainable and the peripheral pulse was not palpable, but respiration continued normally for several minutes. A rapid, irregular pulse was felt over the precordium.

Anesthesia was discontinued, 100-percent oxygen was given, and attempts were made to improve circulation by tilting the patient head down and giving vasopressors. Ten minutes later moist rales were heard in the lungs, and frothy, blood-tinged mucous was aspirated from the trachea. A diagnosis of pulmonary edema was made. Digoxin (1 mg) was given, and an infusion of 5-percent dextrose in water was started in a vein. Norepinephrine was added to the infusion. No central pulse was palpable or audible, and 27 minutes after the peripheral pulse disappeared the chest was opened and manual massage of a flabby, arrested heart was begun. Spontaneous contractions of the heart recommenced but, despite continued treatment, failed to sustain an effective circulation. Four hours after anesthesia was started the patient was pronounced dead.

Comment. Some unknown event, possibly related either to the administration of the general anesthetic or of the local anesthetic and adrenalin, caused a failure of the circulation. Although its occurrence was noted within 5 minutes at the most, the magnitude and significance of this failure were not recognized until 27 minutes after it was first noticed. All subsequent heroic efforts to restore circulation were ineffective.

An electrocardiogram or a continuously indicating blood-pressure monitor would have provided evidence of a change in the function of the heart as soon as it occurred, and an electroencephalogram would have provided clear evidence of circulatory inadequacy within a minute of its occurrence. Delay in establishing a diagnosis insured the fatal outcome of this case.

Case 2. A well-developed, febrile, male infant, aged 12 months, was admitted for treatment of right otitis media and acute mastoiditis. His temperature was 39.8°C, his pulse rate was 160 beats per minute, and his respiratory rate was 80 per minute. On physical examination he appeared acutely ill and irritable, but with no gross abnormalities of his head, chest, abdomen, or extremities. He received nothing by mouth on the day of operation. He was given 15 milligrams of meperidine by hypodermic injection at 11:45 A.M. At 2 P.M. anesthesia was induced with ether, and it was maintained with 50-percent ethylene and ether in oxygen. One hundred milliliters of 5-percent dextrose in water was administered during the operation. A simple mastoidectomy was performed, the operation lasting 60 minutes. His course in the operating room appeared uneventful, and he was returned to the recovery room in fair condition 90 minutes after anesthesia was started. At 4:30 P.M., 1 hour after his admission to the recovery room, his respiration became labored, his fingernails became cyanotic, and his rectal temperature was found to be 42.3°C. Cyanosis deepened; resuscitative measures were taken, but his condition worsened and he was pronounced dead at 5 P.M.

Comment. Dehydration and heavy surgical drapes may cause hyperthermia during warm weather, especially in children. Continuous observation of rectal temperature with a thermistor probe thermometer would almost certainly have forestalled this unnecessary fatality.

Case 3. A well-developed man, age 60 years, was admitted with the complaint of abdominal distension, and cramping abdominal pain of 2 months' duration. Findings on physical exami-

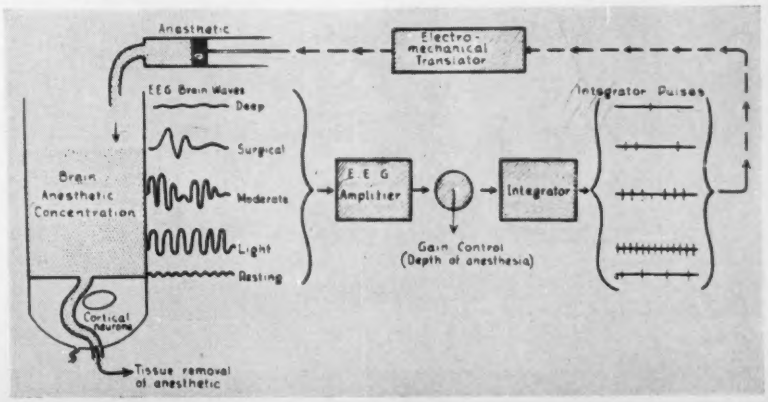


Fig. 2. Schematic diagram of a servo system for controlling depth of anesthesia. [Courtesy Bickford *et al.*]

nation were normal except for abdominal distension. In laboratory analyses of blood and urine constituents and serum electrolytes, the results were within normal limits. The electrocardiogram was normal except for tachycardia. An x-ray examination of the abdomen was compatible with a diagnosis of obstruction of the distal small bowel. A decompression tube was introduced, and the patient was prepared for exploratory laparotomy. Anesthesia was induced with 250 milligrams of thiopental and maintained with ethylene and ether in oxygen. An attempt to introduce an endotracheal catheter failed, but a satisfactory airway was produced with oropharyngeal and nasopharyngeal tubes. During exploration of the abdomen the patient's pulse remained steady, and except for a mild depression of his blood pressure and a moderate increase in respiratory rate, his course was considered to be satisfactory. The bowel was decompressed. Immediately afterward his blood pressure was unobtainable and cyanosis developed. Despite forced infusion of whole blood and artificial respiration with 100-percent oxygen after an emergency trachetomy, he died. A carcinoma of the cecum was found to be responsible for his preoperative symptoms.

Comment. The information available does not reveal the immediate cause of death. Rate of respiration is not an adequate measure of adequacy of pulmonary ventilation. The blood pressure and pulse rate may remain stable during wide variations of total-body blood flow. The origin of the heartbeat may become grossly abnormal without this being detectable by palpation of the pulse. It seems probable that in this case valuable time was lost in ascertaining that respiratory exchange was sufficient. It cannot be determined whether a cardiac arrhythmia, appearing in response to strong visceral stimulation, was responsible for failure of the circulation, or whether the failure was due to sudden pooling of blood in the splanchnic vascular system as a result of rapid reduction of intra-abdominal pressure. Answers to these questions might have been provided by a device that could be used to measure respiratory exchange, by an electrocardiograph, and by an instrument sensitive to the oxygen saturation of central venous blood.

This sort of thing happens only a few times each year in most clinics, but even once is too often if it can be prevented. Our ability to predict these occurrences is directly dependent on the extent of our knowledge of what is going on.

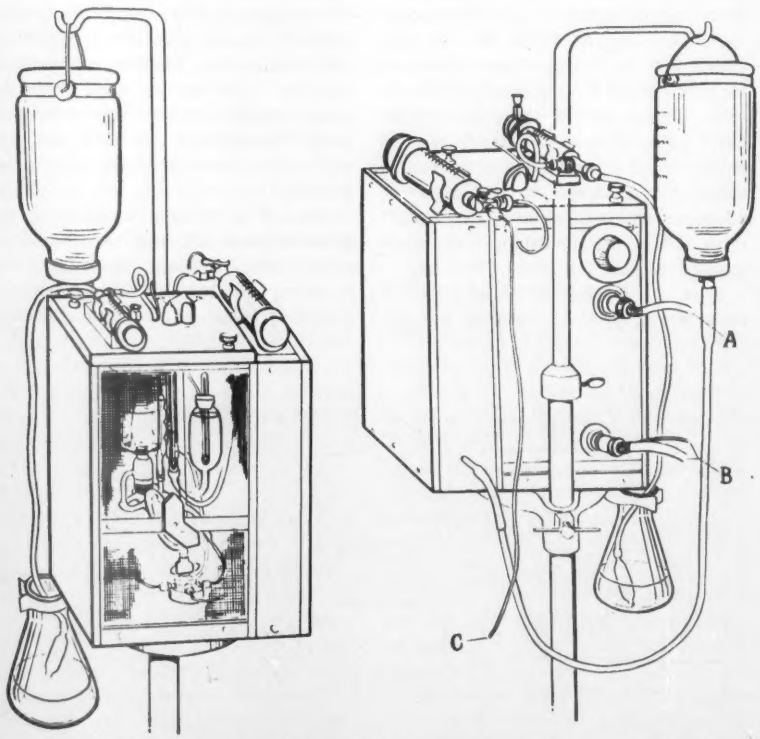


Fig. 3. A thermostated glass electrode probe for rapid, serial measurements of blood *p*H. (Left) Front view, showing position of glass electrode and external controls. (Right) Back view, showing connections: *A*, to power source for heater elements; *B*, to potentiometer; *C*, to arterial cannula.

Recent Developments

The foregoing histories do not give an entirely fair picture of what we can do today. There has been considerable activity among clinical researchers and instrument manufacturers in the last decade to develop devices for regulating more accurately the administration of anesthetic drugs, for controlling respiration, and for providing more reliable information on depth of anesthesia and circulatory status. Described below are a few devices which either have found their way into clinical practice, have shown promise but have required additional engineering, or have served as a basis for clinical studies which have provided new insights into the nature of the state of anesthesia. I make no attempt to present an exhaustive list of the instruments that are available. The examples used for illustration were selected without regard to comparative quality or efficiency of operation.

1) Frumin and Lee (*1*) successfully designed a machine (Fig. 1) which automatically samples exhaled air at the end of expiration, measures its carbon-dioxide tension, and, by means of a servo system, adjusts the inflating pressure of a mechanical lung ventilator to maintain the carbon-dioxide tension at any desired level. The system incorporates a nitrous oxide–oxygen mixing system to provide anesthesia as well.

2) Servo systems have also been used by Bickford and his associates (*2*) and by Bellville and his associates (*3*) for automatically regulating the depth of anesthesia by feeding back information obtained from the electroencephalogram to control the administration of anesthetic drugs. Figure 2 illustrates one scheme for converting monitored information to regulate administration of an anesthetic agent.

3) An explosion-proof, thermostated *p*H probe (Fig. 3) was constructed in the anesthesiology laboratory at Columbia University (*4*), for making serial measurements of the arterial blood during surgical operations. Rendering monitoring equipment safe for

use in the neighborhood of explosive gas mixtures is important in designing an electrical device for use by anesthetists. This *p*H monitor has been very useful for studying alterations in respiration and metabolic response during anesthesia.

4) Ten or more companies manufacture devices suitable for monitoring the electrocardiogram in the operating room. To my knowledge only two instruments have been approved by the Underwriters' Laboratory as explosion-proof, although several others have been designed to reduce the hazard in the event of an explosion. Figure 4 shows a device, based on the work of Zoll and his associates (*5*), which displays the electrocardiogram and sounds an alarm if the pulse interval falls below a predetermined level, simultaneously beginning to send electric stimuli to the heart to maintain cardiac action. Obviously, this device does not provide for support of the circulation, beyond displaying the abnormal rhythm if ventricular fibrillation is the cause of failure, but it will be helpful in the event of complete heart block or cardiac arrest (*6*).

5) A host of miniaturized pulse monitors, all very similar, have appeared on the market in recent years. These are small, highly portable instruments, usually battery-operated transistor circuits which detect the pulse by means of a microphone strapped or taped to the finger, or by sensing the QRS complex of the electrocardiogram through two needles or plate electrodes. The signal is either a flashing light, a flicking meter needle, or a deflection of the meter movement that indicates average pulse rate. A highly desirable feature of some instruments is the conversion of the pulse to an audible signal—a click, squeak, or chirp—which eliminates the need for looking constantly at the device. The pulse monitor illustrated (Fig. 5) allows for alternate inputs, either a microphone or electrocardiogram electrodes. It is based on a design by Severinghaus (*7*).

6) Automatic, indirect blood-pressure monitors are beginning to appear. These detect the peripheral pulse with a microphone or photoelectric device, automatically inflate a cuff on the finger or arm, and indicate the pressure at which the pulse just disappears (the systolic blood pressure). The monitor illustrated in Fig. 6 employs a variable capacitance microphone on the finger and an adjoining inflatable cuff. Each detected pulse operates a solenoid valve which admits a measured amount of air into the cuff. An adjustable leak in the cuff allows the cuff pressure to hover continuously around the systolic pressure. This pressure is displayed by means of an anaeroid manometer.

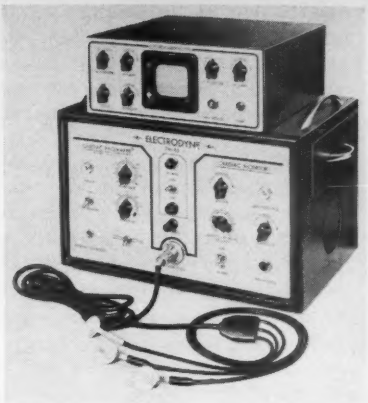


Fig. 4. The Electrodyne cardiac monitor and pacemaker with electrocardioscope.

7) Oximeters, devices which indicate oxygen saturation of the blood by distinguishing between the color of oxygenated and reduced hemoglobin in the lobe of the ear, have been used in numerous clinics during the last decade to determine the adequacy of gas exchange in the lungs. More recently, polarized platinum or gold electrodes covered with thin plastic films, with current-carrying capacity directly dependent on the partial pressure of oxygen, have been used for the same purpose (*8*, *9*).

8) Infrared analyzers (*10*), specifically sensitized to carbon dioxide or to one of several gaseous or volatile polyatomic anesthetic agents, have been employed to measure exhaled carbon dioxide, as in the Frumin and Lee device (Fig. 1) described above, or to follow the uptake and excretion of anesthetic substances. Gas chromatography has made it possible to measure simultaneously a number of the constituents of a mixed-gas sample. These methods are too cumbersome for routine clinical use, and the cost of the equipment is very high, but much information of value has been obtained through using them in clinical research.

9) Devices for measuring respiration that are somewhat cruder but more practical from the standpoint of the clinician are a group of pneumatic and pneumatic-mechanical devices sensitive to flow of air. These include the Ohio minute volume meter (Fig. 7), which is a simple venturi tube with an associated pneumatic integrator, and which tends to indicate the average level of ventilation; the ventimeter (*11*), which is a rebreathing bellows in a calibrated plastic dome, and which indicates the volume of each respiration; the Wright anemometer, a British invention which is a pneumatic turbine operating a watch-type dial indicator; the Bennett respiration meter, which is a light, wooden cogwheel movement indicating gas flow on a dial.

During open heart operations, when a mechanical pump and oxygenator system is temporarily substituted to perform the functions of the heart and lungs, it is not unusual for eight or ten physiological parameters to be monitored. These might include blood pres-

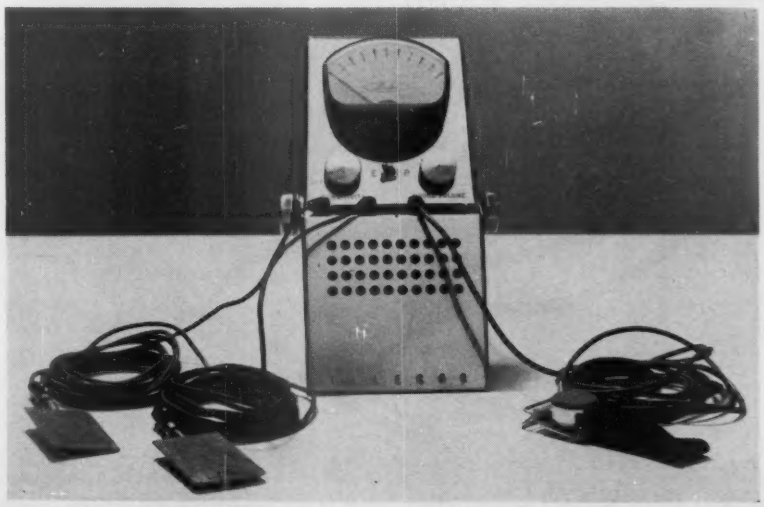


Fig. 5. The Burdick, Inc., Telecor.

sure at two or three sites, total blood flow, oxygen saturation, blood *p*H, carbon-dioxide concentration and hematocrit, blood coagulability, hemolysis, the electrocardiogram, and the electroencephalogram. However, such monitoring requires an electronic technician and at least one other person in the operating room and two or three chemical technicians outside in a laboratory. Obviously this is not practicable as routine procedure in the operating room.

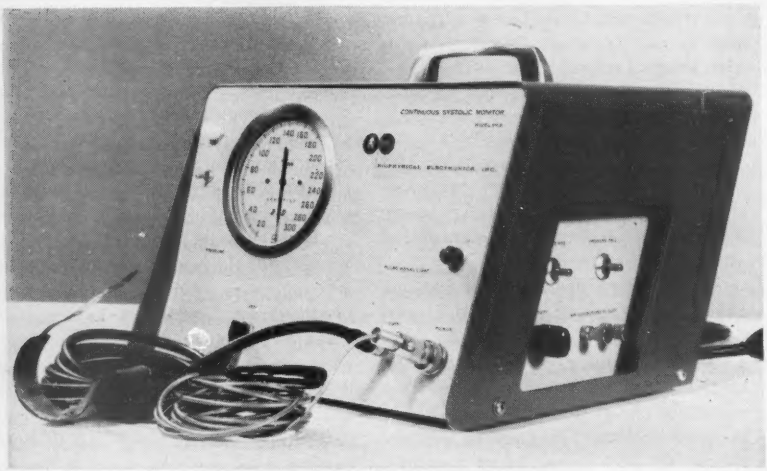


Fig. 6. The continuous systolic monitor.

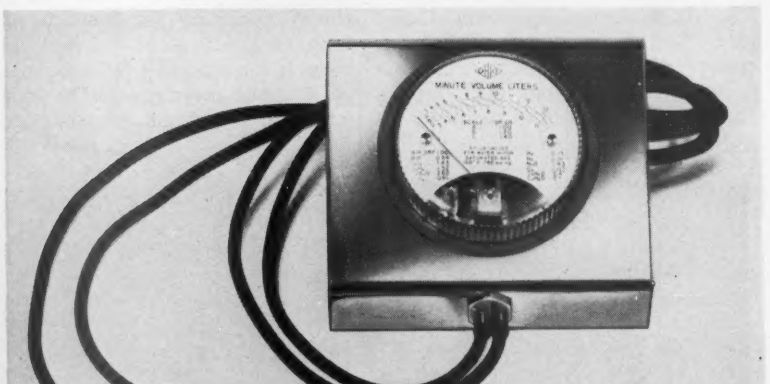


Fig. 7. The Ohio minute volume meter. [Courtesy Ohio Chemical and Surgical Equipment Co.]

Shortcomings of Instruments

There appear to be several reasons why these recent developments have not been incorporated into routine practice.

1) All of these devices are portable; hence, setting them up adds to the time required to prepare the patient for anesthesia and surgery. Also, they are not always available; somebody else may be using the instruments, or a part may be missing.

2) Interpretation of the information presented by the instruments is sometimes difficult. This results from several factors. The clinician may be unfamiliar with the signals that are being presented. False signals may be generated due to artifacts resulting from movement or from signals generated by other equipment in the area. Equipment failure occurs too frequently, as a result of interference or dislodgment of leads and cables. And finally, the information presented by many of these instruments is not particularly useful or reliable. An example of this is the information given by instruments that monitor the pulse. These devices consist usually of some sort of transducer, attached to the finger tip, which is activated by a change in the volume of the finger tip. Occasionally these instruments fail to detect a pulse signal as a result of purposeful peripheral vasoconstriction when the more vital, central circulation is quite adequate. On the other hand, electrocardiograms have been obtained from patients whose hearts have ceased to have any effective pumping action.

3) Many of these instruments consist of bulky and multiple chassis accompanied by a bale of lines, lead cables, and so forth. Such machines contribute unduly to the general confusion of the operating room. This is disturbing to the anesthetist and is resented by other teams in the operating room.

4) The use and maintenance of this type of equipment is frequently beyond the competence of the anesthesiologist, and hence he views it with suspicion and is reluctant to accept it.

Possible Solutions

All of these problems are soluble, but investment of time and money is required for further development. In seeking to improve this instrumentation, first, the acceptability of permanent installations in the operating room should be tested. If automatic control systems and monitoring devices were made more readily available, clinicians would use them more often and the development of improved devices would be accelerated. Second, transmission systems should be simplified, as through telemetering. Telemetry is a science that has been developed to a very high degree for the astronautical industry. Surely, only minor modifications should be required to produce a miniaturized transmitter and multiplexer with at-

tached sensing elements which could be plastered unobtrusively to the patient before he is brought to the operating room. Upon his admission to the operating room the necessary intelligence could be picked up by a permanently installed wall receiving-and-display unit. William Thornton has devised a system of this sort, which is being used successfully by the anesthesiologists at the University of North Carolina (*12*). And finally, we should attempt to develop new sensing elements and data-processing systems to provide more positive information. Electrical impedance plethysmography, as conceived by Nyboer (*13*), may furnish evidence of alternations of regional blood flow during anesthesia about which we can do little more than guess at the present time.

Similar challenges exist in practically every phase of medical practice and biological research. Our methods of diagnosis can probably be speeded by application of modern computer techniques for correlating the information obtained from the medical history of the patient, the physical examination, and laboratory data. Zworykin is experimenting in this area in collaboration with physicians at New York Hospital and Mt. Sinai Hospital, New York (*14*). Methods of keeping medical records and recalling information can probably be made more efficient and certain by applying modern data-recording principles such as every other important industry relies upon today. Nursing techniques can be performed by mechano-electrical systems in many instances; for example, thermistor or thermocouple thermometers are wired from each patient's bed to a central display and recording unit in some Scandanavian hospitals. Pulse and respiratory rates could be similarly monitored and transmitted to the nursing station. This would enable us to make better use of our nurses, who are in very short supply today. Machines are being perfected which will scan blood slides and tissue slides for evidence of malignancy and other disorders. These can speed diagnosis and further reduce the number of personnel required to attend each patient (*15*). Routine clincal chemical analyses are now being performed in a number of hospitals more reliably and more rapidly by machines (*16*), designed on principles utilized by the chemical industries for several decades.

These are examples of ideas for improving medical practice through application of instrumentation and automation that have already occurred to workers in this field. A few of these ideas are already being proved practical, but most of our medical institutions continue to ignore them.

Why are we still so far behind? There are too few scientists of the caliber of Zworykin and his associates at the Medical Electronics Center of the Rockefeller Institute and the Radio Corporation of America Laboratories, and of Robert Bowman's group at the Laboratory of Technical Development of the National Heart Institute, who are willing to apply themselves to this work. And there are still too few companies willing to gamble on this undeveloped market. Also to blame are members of the medical profession and hospital administrators who have not learned to appreciate fully the advantages to be derived through abandoning traditional methods. And this brings us to another roadblock.

Physicians, by virtue of their specialized training in the medical sciences, are not equipped to undertake this type of development by themselves. And engineers are equally unable to produce satisfactory solutions because they lack understanding of the physician's problem. There, are two obvious solutions to this dilemma. One is to educate a number of physicians in the engineering sciences. This will undoubtedly become a more common procedure in future years, as instrumentation becomes a more commonplace part of medicine, but at best it will be a slow process. A more immediate solution is to bring engineers into our hospitals and medical research laboratories, where they can become acquainted at first hand with our problems and, even more important, can participate in the field trials which determine whether or not a given line of development is feasible. To meet the long-term need for more engineers interested in biomedical instrumentation, research institutes and training centers will have to be established. The Russians have shown the practicality of such units with their successful Institute of Experimental Surgical Apparatus.

Our scientific societies can play an important part in effecting these changes. The more these problems are talked about, the more urgent will be the demand for their solution. Among the several thousand scientific and technical organizations in the United States there is as yet not one national society devoted exclusively to advancing medical instrumentation. Only one organization has significant representation of regularly active local groups throughout the country—the Institute of Radio Engineers' Professional Group on Biomedical Electronics. Members of the Instrument Society of America have made a few valiant attempts to initiate a national program but have met with frustration as a result of having to compete with too many established interests. Other engineering societies have had similar experiences. The medical and biological societies have failed to advance even this far.

Lastly, advancement will depend also upon the accumulation of a substantial and authoritative literature devoted to medical instrumentation. The *IRE Transactions on Medical Electronics*, the bibliography on medical electronics which is prepared by the Medical Electronics Center of the Rockfeller Institute and published by the Professional Group on Medical Electronics, the proceedings of the new instrumentation division of the New York Academy of Sciences, the digest of technical papers based on the annual Conferences on Electrical Techniques in Medicine and Biology, the annual instrument issue of *Science*, and similar publications represent the sound beginning that has been made in establishing useful library and communications media in this young but promising field of science.

References

1. M. J. Frumin and A. S. J. Lee, *J. Lab. Clin. Med.* **49**, 617 (1958).
2. R. G. Bickford, *Electroencephalog. and Clin. Neurophysiol.* **2**, 93 (1950); D. E. Soltero, A. Faulconer, Jr., R. G. Bickford, *Anesthesiology* **12**, 574 (1951).
3. J. W. Bellville and G. M. Attura, *Science* **126**, 827 (1957).
4. D. A. Holaday, *J. Lab. Clin. Med.* **44**, 149 (1954).
5. P. M. Zoll, *New Engl. J. Med.* **254**, 541 (1956).
6. M. J. Nicholson, U. H. Eversole, R. B. Orr, J. P. Crehan, *Current Researches in Anesthesia & Analgesia* **38**, 335 (1959).
7. J. W. Severinghaus, *Anesthesiology* **18**, 145 (1957).
8. E. H. Wood, in *Medical Physics*, Otto Glasser, Ed. (Year Book Publishers, Chicago, 1950), vol. 2, p. 664.
9. J. W. Severinghaus and A. Freeman Bradley, *J. Appl. Physiol.* **13**, 515 (1958).
10. W. H. L. Dornette and V. L. Breckner, *Instrumentation in Anesthesiology* (Lea and Febiger, Philadelphia, 1959), chap. 14.
11. J. O. Elam, J. L. Evers, C. D. Janney, *N.Y. State J. Med.* **59**, 4543 (1959).
12. D. A. Davis, D. C. Grosskreutz, K. Sugioka, W. Thornton, presentation at the annual meeting of the American Society of Anesthesiologists (1960).
13. J. Nyboer, *Electrical Plethysmography* (Thomas, Springfield, Ill., 1959).
14. V. K. Zworykin, *1959 IRE Conv. Record* (1960), pt. 9, pp. 42–46.
15. R. C. Bostrom, H. S. Sawyer, W. E. Tolles, "Instrumentation for automatically prescreening cytological smears," *Proc. I.R.E. (Inst. Radio Engrs.)* **47**, 1895 (1959).
16. *Ann. N. Y. Acad. Sci.* **87**, 609 (1960).

Fuel Cells

They produce more electricity per pound of fuel than any other nonnuclear method of power production.

Ernest Yeager

In a postscript to a letter to the editor of *The Philisophical Magazine* in 1839, Sir William Grove (*1*) first reported the production of electrical energy by means of an electrochemical cell consuming hydrogen and oxygen gases. In his postscript Grove was not concerned with the generation of electrical power but rather with the demonstration that the electrolysis of water on platinum electrodes could be reversed. Grove's cell was capable of doing nothing more than deflecting a galvanometer. Nevertheless, this work was the forerunner of present-day fuel cells. Of the various fuel cells now available, the hydrogen-oxygen fuel cells appear to be the most advanced.

Much of the incentive for work on fuel cells in the latter half of the 19th century and the early 20th century was derived from the desire to burn coal electrochemically at efficiencies far higher than is possible with conventional heat engines. The direct electrochemical combustion of coal has not yet been accomplished on a practical basis, but other fuels, including some derived from coal, have been used successfully in electrochemical cells.

In the broad sense, any anodic reactant in a battery can be considered a fuel. Originally the designation "fuel cell" was reserved, however, for electrochemical cells which were to generate power from low-cost fuels. In recent years the term has been extended to include electrochemical cells consuming fuels which hardly can be considered low in cost. Projected space applications and exotic military applications, in good part, have prompted this extension of the term.

A particular feature of almost all fuel cells is that the electrode reactants are not stored in appreciable amounts within the cells but are fed into the system as they are consumed, usually in a continuous fashion. Thus, only a relatively small amount of either the fuel or the oxidizing agent is within the cell at any instant. The oxidizing agent for fuel cells, with few exceptions, is either pure oxygen or oxygen derived from air, since other oxidizing agents, such as the halogen gases, are far more expensive, heavier, and more difficult to handle than oxygen.

In the ordinary combustion of a fuel, the electrons are rearranged within the molecules and transferred between molecules without the opportunity to do any useful work directly, and hence their excess energy is degraded to heat. Only a portion of this heat can be converted to useful work or electrical energy by means of a heat engine because of limitations imposed by thermodynamics. Thus the efficiency (f) associated with the conversion of chemical to electrical energy with a heat engine is set by the Carnot-cycle expression:

$$f = \frac{W}{Q} = \frac{T_2 - T_1}{T_2} \qquad (1)$$

where W represents the work derived from the heat engine, Q represents the heat introduced into the heat engine at the higher temperature T_2, and T_1 represents the lower temperature at which heat is rejected to the surroundings. In the most advanced types of turboelectric generating equipment available today, not much more than 40 percent of the chemical energy released as heat during the combustion of the fuel can be converted to electrical energy.

During electrochemical oxidation, the electrons are transferred from the fuel to the oxidizing reactant (usually oxygen) through an external electrical circuit and hence can lose much of their excess energy by doing useful electrical work. As a result, the efficiency associated with the conversion of chemical to electrical energy in an electrochemical cell is not limited by the Carnot cycle equation mentioned previously (Eq. 1). The theoretical limit for the thermal efficiency of an electrochemical cell is given thermodynamically as

$$f = \frac{W}{Q} = \frac{\Delta F}{\Delta H} \qquad (2)$$

where W is the electrical work derived from the system; Q is the heat that would have been released if the fuel were oxidized directly, nonelectrochemically; ΔF is the free energy of oxidation of the fuel; and ΔH is the enthalpy (or heat content) of oxidation of the fuel. Since ΔF is numerically somewhat less than ΔH for the fuel cells now under development, the efficiency for these cells must be less than unity. Actual values for f in excess of 60 percent have already been achieved for some of these cells.

In addition to more electrical energy per pound of fuel, fuel cells offer the potential advantages of relative simplicity and long life in unattended operation. High-speed moving parts operating in high-temperature environments, such as are encountered with conventional heat engines, are not involved. Fuel cells, however, provide low-voltage direct-current power rather than alternating-current power—a decided disadvantage in certain types of applications.

Despite the present enthusiasm in the United States for fuel cells, no system as of this date appears to have advanced beyond the developmental stage, and many are still at the basic research level. This situation does not reflect a lack of effort but reflects, rather, the substantial technical difficulties which must be overcome before practical fuel-cell systems are available.

Polarization

When power is drawn from an electrochemical cell, the terminal voltage of the cell decreases from that which would be anticipated thermodynamically. This decrease in cell voltage reflects not only IR drop within the cell but also potential losses associated with irreversibility of various processes at the electrode-solution interfaces. These

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deviations in the potentials of the electrodes from the values predicted thermodynamically are referred to as electrode polarization. Many electrochemical fuels which appear to be advantageous for fuel-cell applications on a thermodynamic basis cannot be used successfully because of excessive electrode polarization which prohibits the operation of the cells at practical power levels; that is, whenever any appreciable current is drawn from the cells, the cell voltage rapidly drops to a very low value.

The reversibility of a given electrode reaction, and therefore the electrode polarization, is often very dependent upon the catalytic properties of the electrode surface. For example, the electrochemical oxidation of hydrogen at a given electrode potential may be able to proceed 10^3 to 10^6 times faster with a platinum-impregnated porous carbon electrode than with a similar carbon electrode containing no such catalyst. Part of this improved performance with the platinum catalyst is due to the intrinsic catalytic properties of platinum for the hydrogen oxidation reaction, while part is due to the very high surface area associated with the platinum metal as it is incorporated in the carbon electrodes. Fundamental electrochemical research on the kinetics of electrode processes on various surfaces should prove of considerable importance in the future in pointing the way to development of more active surfaces for use as electrodes in fuel-cell systems operating at high current densities with a minimum of polarization.

Specific Systems

In Table 1 are listed various fuel cells which appear to offer promise, and of which the performance has been documented in the literature or in published reports. All of the cells listed in Table 1 operate on oxygen. In some instances, however, it is not practical to derive the oxygen by feeding air directly to the cells, for reasons which will become evident in the evaluation of the specific systems.

Hydrogen-oxygen cells. The hydrogen-oxygen cells of Union Carbide (*2*), Bacon (*3*), and Justi (*4, 5*) listed in Table 1 all operate with strongly alkaline electrolytes. Alkaline electrolytes (usually KOH) have generally been favored because the reduction of oxygen at the cathode proceeds with a minimum of polarization in such solutions. The over-all reactions for these cells with alkaline electrolytes are as follows:

$$\text{Anode: } 2H_2 + 4OH^- \rightarrow 4H_2O + 4e^- \quad (1)$$

$$\text{Cathode: } O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \quad (2)$$

$$\text{Cell: } 2H_2 + O_2 \rightarrow 2H_2O. \quad (3)$$

Thus the over-all cell reaction involves the generation of water from hydrogen and oxygen.

If no voltage losses occurred within hydrogen-oxygen fuel cells, the voltage expected thermodynamically should be slightly in excess of 1.2 volts, the value corresponding to the free-energy change associated with reaction 3 at temperatures below 100°C. In practice, cell voltages for the hydrogen-oxygen system rarely exceed 1.05 volts, and the operating voltages under load conditions do not exceed 0.9 volt, because of electrode polarization as well as IR drop within the cells.

Figure 1 is a functional diagram of a hydrogen-oxygen cell with an aqueous electrolyte. Porous electrodes are used to permit the sparingly soluble reacting gases (hydrogen and oxygen) to pass through the electrodes from the rear to the sites of the electrochemical reactions at the solution-electrode interfaces. Under proper operating conditions the electrolyte should penetrate only into the outermost pore structure of the electrode. Pores in the bulk of the electrodes should be free of solution, since the diffusion of sparingly soluble gases through liquid-filled capillaries is far too slow for operation at reasonable current densities.

One means of keeping the pores within the bulk of the electrode free of solution is to have the surfaces within the pores hydrophobic, as is the case with the porous carbon electrodes used in the Union Carbide hydrogen-oxygen cell. In such porous electrodes interfacial tension is the predominant factor which keeps the pores from filling with solution. With time and use, however, the hydrophobic properties of the electrode may be slowly modified and the solution may progressively penetrate into the pore structure, with the result that the electrodes eventually fail to function properly. The penetration of the solution into the pores of the hydrophobic-type electrodes is usually accelerated by operation at high current densities.

Table 1. Typical fuel cells.

Systems	Reactants	Electrode		Electrolyte	Typical temperature	State of development	Remarks
		Anode	Cathode				
Union Carbide (*2*)	$H_2 + O_2$	Carbon	Carbon	KOH	20°–60°C	Advanced	Requires H_2 free of CO and CO_2
Bacon (*3*)	$H_2 + O_2$	Ni	Ni	KOH	200°–240°C	Advanced	Requires 400 to 800 lb/in.^{2}; requires H_2 free of CO and CO_2
Justi (*4, 5*)	$H_2 + O_2$	Ni	Ag	KOH	20°–90°C	Moderately advanced	Requires H_2 free of CO and CO_2
G.E. ion-exchange membrane (*11*)	$H_2 + O_2$	Pt	Pt	Resin	20°–80°C	Advanced	No fluid electrolyte
Fused carbonate (*14, 17, 18*)	$H_2 + O_2$	Porous metals	Porous metals	Alkali metal carbonates	400°–600°C	Early	Capable of operation on H_2 containing CO and CO_2
Fused carbonates (*16–19*)	Hydrocarbon + O_2	Porous metals	Porous metals	Alkali metal carbonates	500°–700 C	Early	Deterioration of electrodes and gaskets at high temperatures a problem
Esso (*20*)	Hydrocarbon + O_2	Porous carbon plus catalysts	Porous carbon plus catalysts	KOH	65°–200°C	Early	Problem of CO_2 rejection from electrolyte, not solved
Alcohol cells (*5, 10*)	Alcohol + O_2	Porous metals	Porous metals	KOH	20°–90°C	Early	Problem of CO_2 rejection from electrolyte, not solved
Allis Chalmers alcohol-peroxide (*10*)	Alcohol + H_2O_2	Pt	Ag	NaOH	20°–45°C	Early	Available in the form of student demonstration kit; rather inefficient
Amalgam cell (*22*)	Na(Hg) + O_2	Steel	Carbon	NaOH	20°–70°C	Moderately advanced	Expensive to operate

With porous metal electrodes the internal surfaces are hydrophilic, and an excess pressure must be maintained in the gas phase at the rear of each electrode to prevent the electrolyte from flooding all the pores of the electrode. Gas bubbles, however, should not be forced into the solution, since such bubbles would interfere with cell operation. For this and other reasons, such porous metal electrodes are usually constructed with a relatively coarse pore structure for most of the electrode and a fine-pore-structure layer on the side of the electrode facing the solution. A stable zone for the gas-liquid interfaces can be established within the pores in the transition region from the coarse- to fine-pore layers by maintaining an excess gas pressure behind the electrode. With this arrangement some fluctuations in pressure can be tolerated without the electrode flooding or gas bubbles being blown into the solution.

The coarse and fine pores just described have radii in the range of 10^{-4} to 10^{-3} centimeter and often are referred to as macropores. In addition to the macropores, the electrodes used in hydrogen-oxygen cells have a micropore structure, involving pores principally of dimensions 10^{-5} to 10^{-7} centimeter. The micropore structure may be obtained either by coating the inside of the macropores with a microporous layer or by incorporating the microporosity within the material from which the electrodes are fabricated. The presence of the micropore structure within the electrodes greatly increases the solid-solution area where the electrochemical reactions occur. Very large internal areas often are required if the electrochemical reactions are to be carried out at appreciable rates—that is, if appreciable currents are to be drawn from the electrochemical cells.

Union Carbide hydrogen-oxygen cell. In the Union Carbide cell, hydrogen and oxygen (or air) are fed through porous carbon electrodes with concentrated potassium hydroxide as the electrolyte. The catalysts incorporated in the porous carbon anodes are extremely effective in catalyzing the electrochemical oxidation of hydrogen according to reaction 1, and hence, relatively little electrode polarization occurs at the hydrogen anode under operating conditions. The potential of the oxygen cathodes, however, deviates considerably from that expected for the four-electron reduction shown in reaction 3. Extensive laboratory studies (*6*) have

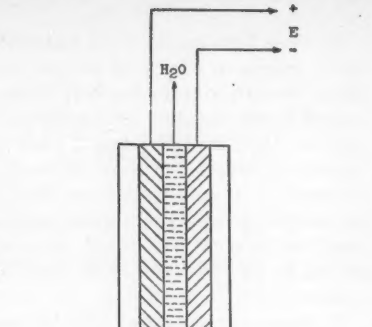

Fig. 1. Functional representation of a hydrogen-oxygen fuel cell.

demonstrated that the cathodic reduction in this cell involves the formation of the perhydroxyl anion (HO_2^-) as an intermediate, according to the reaction:

$$O_2 + H_2O + 2e^- \rightarrow HO_2^- + OH^- \quad (4)$$

Catalysts are incorporated in the cathodes to decompose the peroxide as fast as it is formed, according to the reaction:

$$HO_2^- \xrightarrow{\text{catalyst}} OH^- + \tfrac{1}{2}O_2 \quad (5)$$

The oxygen liberated during the chemical decomposition of the hydrogen peroxide according to reaction 5 is utilized by the cathode in reaction 4, and hence, four equivalents of charge are obtained per mole of oxygen consumed by the cell. Thus, the over-all cathodic reaction is that given by reaction 2. The more effective the catalyst is for reaction 5, the closer the cell voltage should approach the thermodynamic value predicted on the basis of the over-all reaction for the cell (reaction 3). Much research has been, and continues to be, directed toward finding good catalysts for the peroxide-decomposition step.

Water produced as a product in reaction 3 must be removed from the electrolytic solution within the cell as it is formed. The Union Carbide hydrogen-oxygen cells are designed for operation at temperatures usually in the range of 40° to 60°C. In operation at relatively low power levels, sufficient water can be evaporated from the electrolyte directly through the porous electrodes. Unfortunately, most of this evaporation must occur through the porous carbon anode because water is produced at the anode but consumed at the cathode (see reactions 1 and 2). This necessitates the circulation of an excess of hydrogen gas past the rear of the anodes and the condensation of this water out of the hydrogen gas in a separate condenser prior to the recirculation of the hydrogen to the anode. At moderately high power levels, evaporation of the water vapor directly through the porous electrodes may be insufficient to maintain a reasonable electrolyte concentration, and it may be necessary to circulate the electrolytic solution of the cell through an external evaporator to remove water formed by the cell reaction. Thus, a significant amount of auxiliary equipment is required to operate the hydrogen-oxygen fuel cells.

Figure 2 is a photograph of a hydrogen-oxygen battery similar to one which the Union Carbide Consumer Products Company is developing under contract with the U.S. Signal Corps. The battery in Fig. 2 consists of 36 cells in series and has been designed to provide approximately 200 watts at 28 volts in operation on air as the source of oxygen. The catalyst-impregnated semihydrophobic carbon electrodes of this battery are mounted parallel to each other, in an arrangement similar to that shown functionally in Fig. 1. The hydrogen gas and the air are fed to the individual electrodes from manifolds at the ends of the battery, through a network of holes or channels in the plastic frames of the cells. Specific information is not available on terminal voltage in relation to current or the operating life of the battery in Fig. 2. Cells using similar carbon electrodes have been found capable of providing 0.90 volt at a current density (*7*) of 50 amperes per square foot in operation on pure hydrogen and oxygen, each at 1 atmosphere, at 40°C. Furthermore, operational life well in excess of 1 year has been obtained by Union Carbide with similar cells.

Hydrogen-oxygen cells in which carbon electrodes are used have been worked on by other groups, including Davtyan (*8*) in the U.S.S.R. and Justi (*9*) in Germany. None of these other

groups has developed its cells to the advanced state of the Union Carbide system.

Bacon hydrogen-oxygen cell. Bacon (*3*) and his associates at Marshalls in Cambridge, England, have developed a hydrogen-oxygen cell which uses sintered nickel electrodes in a concentrated potassium hydroxide solution and operates at temperatures from 200° to 240°F and pressures of 400 to 800 pounds per square inch. The macropores of the nickel cathodes in these cells are coated internally with a layer of microporous nickel oxide in which lithium has been incorporated as a doping agent. The macropores of the nickel anode are also coated with a microporous layer of nickel. Figure 3 shows a Bacon battery consisting of 40 cells in series, with each electrode approximately 10 inches in diameter. Operation for up to 1500 hours has been achieved with cells of the type used in this battery. The gases are supplied to the rear compartment behind each electrode through a network of channels within the frames of the cells. The Bacon cells must be preheated to at least 150°C before significant power can be drawn from the cells, but self-generated heat should be sufficient to maintain temperature during normal operation. Operation of the Bacon cells on air rather than pure oxygen does not appear feasible because of the need to compress the gases fed to the cells. As with the Union Carbide hydrogen-oxygen cells, water may be removed from the cells as vapor primarily through the anodes. The much higher operating temperatures of the Bacon cells facilitate the removal of water in this manner.

The battery shown in Fig. 3 is capable of supplying 3.2 kilowatts at 32 volts and 100 amperes, or 5.7 kilowatts at 24 volts and 240 amperes. During the past year, since the completion of this battery, Bacon and his colleagues have improved the performance of individual cell units by a considerable amount. With the introduction of these new improvements it should be possible to obtain up to twice as much power with the same size battery. The Bacon cell appears to have the highest power per unit weight or volume of any of the hydrogen-oxygen cells now available.

The Bacon cell is presently being worked on in the United States by the Patterson-Moos Research Division of the Leesona Corporation, the U.S. licensee. The work of Bacon and his associates in England, however, appears to have been discontinued at this time.

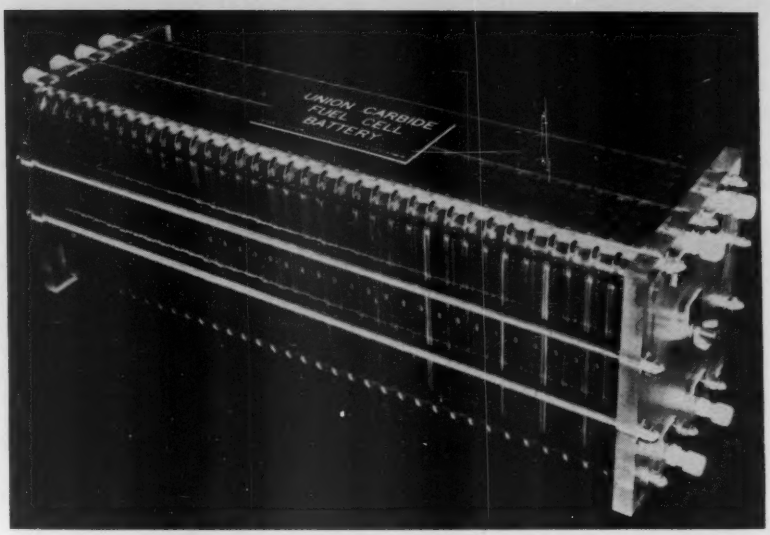

Fig. 2. The Union Carbide hydrogen-oxygen cell. [Courtesy Union Carbide Consumer Products Company]

Justi hydrogen-oxygen cell. Justi (*4, 5*) and his associates at Braunschweig, Germany, have developed a hydrogen-oxygen cell, using hydrophilic, porous silver cathodes and porous nickel anodes in a concentrated potassium hydroxide electrolyte. Justi obtains extremely high catalytic activity in his electrodes by using Raney metals in their preparation. The cells can be operated from room temperatures to temperatures in excess of 90°C at atmospheric pressure. The open-circuit voltage at room temperature is approximately 1.1 volts, while current densities of the order of 100 amperes per square foot have been obtained at terminal voltages of 0.90 volt. Single cell units have been operated for more than a year with no apparent loss in operating characteristics. At this time, information on operating characteristics is available only for relatively small laboratory units.

Other groups which have developed hydrogen-oxygen cells with porous-metal electrodes and caustic solutions

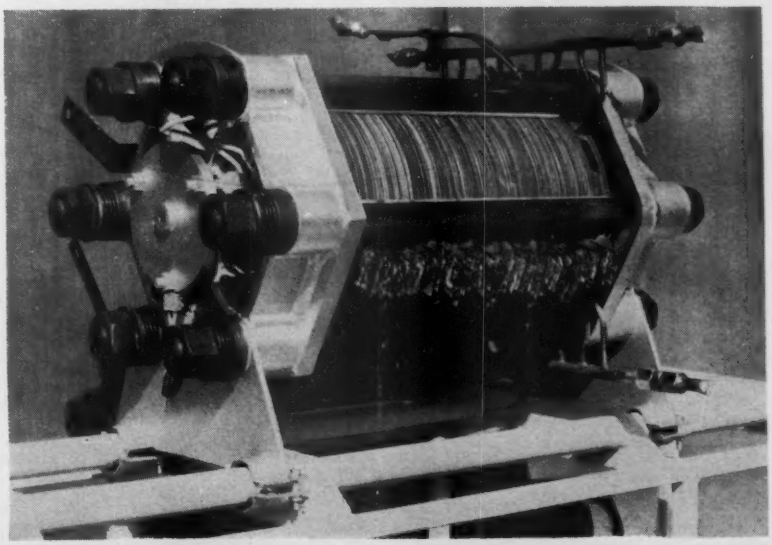

Fig. 3. The Bacon hydrogen-oxygen cell. [Courtesy F. Bacon]

include the Electric Storage Battery Company and the Allis Chalmers Manufacturing Company (*10*). In 1959 Allis Chalmers powered a tractor with such cells. The power plant consisted of 1008 individual cells with a total output of 14 kilowatts. The cells were of the type of construction shown in Fig. 1 and had a cross section of 1 square foot. Each cell provided 0.7 volt at 20 amperes per square foot at a temperature of 150°F. The original announcement concerning the fuel-cell-powered tractor indicated that the cells operated on propane or a propane-hydrogen mixture. In a recent paper (*10*) on this power plant, however, the cells were described as operating on hydrogen, with no indication that they operated on propane or any other hydrocarbon. Thus, the electrochemical oxidation of hydrogen, rather than propane, appears to have been the principal source of power for the tractor. The Allis Chalmers tractor is historically significant, however, as the first large-scale mobile machine to be powered by a fuel cell, even though the source of power appears to have been hydrogen rather than propane. The tractor recently has been transferred to the Smithsonian Institution.

General Electric ion-exchange membrane cell. This cell (*11*) differs drastically from the hydrogen-oxygen cells just described in that the electrolyte is an ion-exchange resin and not a liquid. While anionic-type resins can be used, the best results have been obtained so far with cation-exchange resins in which the conducting species is the hydronium ion (H_3O^+) and the anions are immobile. The membrane, with a thickness of 0.6 to 0.8 millimeter, is sandwiched between two porous metal electrodes containing catalysts (for example, platinum and palladium) for promoting the electrode reactions with a minimum of electrode polarization. These cells are capable of operating with either pure oxygen or air fed through the cathodes. The open-circuit voltage, on hydrogen and either pure oxygen or air at atmospheric pressure, is approximately 1.05 volts at room temperatures and drops to 0.81 volt at 20 amperes per square foot on oxygen, and 0.72 volt at 20 amperes per square foot on air. While these current densities are somewhat lower than those obtained with most present-day hydrogen-oxygen cells, this factor is offset by the thin cell construction possible with the membrane cell. Operation of these cells appears feasible at temperatures from 0° to 100°C.

The electrode reactions and the over-all cell reaction in the General Electric cell with the cation-exchange resins are as follows:

$$\text{Anode: } 2H_2 + 4H_2O \rightarrow 4H_3O^+ + 4e^- \quad (6)$$

$$\text{Cathode: } O_2 + 4H_3O^+ + 4e^- \rightarrow 6H_2O \quad (7)$$

$$\text{Cell: } 2H_2 + O_2 \rightarrow 2H_2O \quad (8)$$

While the over-all cell reaction is the same as for the other hydrogen-oxygen cells, the electrode reactions differ. In this cell, water is produced at the oxygen cathode and consumed at the hydrogen anode, in contrast to the situation for hydrogen-oxygen cells with alkaline electrolytes.

A major advantage of the membrane cell is that water removal is simple, since water tends to form as droplets on the rear surface of the cathode during operation and can be either drained off or evaporated away. In fact, care must be taken not to dehydrate the resin, since the electrical resistance of the membrane decreases drastically when the water absorbed in the membrane decreases below a critical level. In operation on air it is desirable to maintain the relative humidity of the air at least at 25 percent to prevent excessive dehydration of the membrane. Of the various fuel-cell systems developed as of this date, the membrane system appears to require the least auxiliary equipment for its operation.

General Electric is currently developing a portable 200-watt, 24-volt system for operation on air for the U.S. Navy and the Army Signal Corps. Preliminary models of this power package are scheduled for delivery this year. The battery consists of 35 cells in series connection, each cell having the dimensions 9 by 14 by ⅜ inches. The complete system (Fig. 4) is expected to weigh 55 pounds, including all auxiliaries and a sufficient chemical source of hydrogen (metal hydride reacting with water) for operation on air at 200 watts for 24 hours. With replacement of the chemical source of hydrogen gas, continuous operation for up to 2000 hours should be possible. Single-cell units of smaller size have been run continuously by General Electric for periods of almost 2 years.

Other hydrogen-oxygen cells. The General Electric Company (*12*) has also worked on the development of a redox cell in which the chemical reactions for the continuous-feed cells are regenerated from cell products external to the cell by chemical reactions with hydrogen gas and oxygen gas or air. The reactions are as follows:

Electrochemical reactions.

$$\text{Anode: } 2Ti^{3+} + 2H_2O \rightarrow 2TiO^{++} + 4H^+ + 2e^- \quad (9)$$

$$\text{Cathode: } Br_2 + 2e^- \rightarrow 2Br^- \quad (10)$$

$$\text{Cell: } 2Ti^{3+} + Br_2 + 2H_2O \rightarrow 2Br^- + 2TiO^{++} + 4H^+ \quad (11)$$

Regeneration reactions.

$$2H_2 + 4TiO^{++} + 4H^+ \rightarrow 4Ti^{3+} + 4H_2O \quad (12)$$

$$O_2 + 4Br^- + 4H^+ \rightarrow 2Br_2 + 2H_2O \quad (13)$$

Over-all reaction.

$$2H_2 + O_2 \rightarrow 2H_2O \quad (14)$$

The electrolyte of the cell is concentrated sulfuric acid plus the reactants and products indicated in reactions 9 and 10. The major advantage of the redox system is the possibility of using hydrogen containing impurities (particularly CO and CO_2) which would be harmful in the other hydrogen-oxygen cells involving alkaline electrolytes. Unfortunately, technical complications have impeded the development of this and related systems involving such redox reactions.

It is interesting to note that Rideal and Posner (*13*) in England have attempted to regenerate the anodic reactants for a redox cell through the use of coal at somewhat elevated temperatures in an arrangement similar to that described for the hydrogen-oxygen redox system of General Electric. Only a small portion of the coal could be oxidized in this manner, however.

Hydrogen-oxygen cells operating at high temperatures (> 400°C) with fused alkali metal carbonates have received attention both here (*14–16*) and in other countries (*17–18*) including the U.S.S.R. (*8, 19*). The reactions in these cells are as follows:

$$\text{Anode: } 2H_2 + 2CO_3^{--} \rightarrow 2H_2O + 2CO_2 + 4e^- \quad (15)$$

$$\text{Cathode: } O_2 + 2CO_2 + 4e^- \rightarrow 2CO_3^{--} \quad (16)$$

$$\text{Cell: } 2H_2 + O_2 \rightarrow 2H_2O \quad (17)$$

While carbon dioxide is formed at the anode, the same amount of carbon dioxide must be introduced with the oxygen to the cathode. The transfer of anodically formed carbon dioxide to the cathode is not a simple operation.

Three types of fused carbonate hydrogen-oxygen cells are under investigation. In one type, porous metal

electrodes are placed in contact with the fluid fused carbonate electrolyte in an arrangement similar to that shown in Fig. 1. In the second type, the fused carbonates are contained within a porous ceramic disk with thin porous metal electrodes attached to the opposite sides of the disk. Thermal cracking of these disks, however, is a common occurrence, and this has prompted Broers at the University of Amsterdam to propose a third method of construction involving the use of an alkali metal carbonate-magnesium oxide paste placed between two porous metal electrodes.

These high-temperature cells are capable of operating on either H_2 or H_2–CO mixtures, but their development has been delayed by such undesirable features as rapid degeneration of cell components at high temperatures, the need to supply carbon dioxide in the oxygen feed, and relatively low power output per unit weight.

Hydrocarbon-consuming fuel cells. Potentially by far the most important fuel cells are those consuming hydrocarbons such as natural gas or oil. Unfortunately the electrochemical oxidation of hydrocarbons is much more difficult to accomplish than the electrochemical oxidation of hydrogen.

Fused alkali metal carbonate cells have been operated on hydrocarbons such as propane (*16, 17*) and gasoline (*19*) at temperatures above 500°C. Such operation usually has been obtained only for a few days and, in many cases, a few hours before the failure of cell components, primarily because of the high temperatures. Satisfactory gaskets are yet to be found. The development of practical, high-temperature cells operating on readily available hydrocarbons appears to be at least 10 years in the future.

Through electrochemical oxidation of a hydrocarbon in an aqueous cell at moderately low temperatures, complications associated with high-temperature operation would be avoided. The Esso Research and Engineering Company (*20*) has reported the development of a small laboratory cell which can operate on ethane, propane, or ethylene with a concentrated aqueous potassium hydroxide electrolyte and a porous oxygen cathode at temperatures of 65° to 200°C. With ethane, the electron yield has been found to be 13.8 electrons per molecule consumed as compared with the theoretical value of 14.

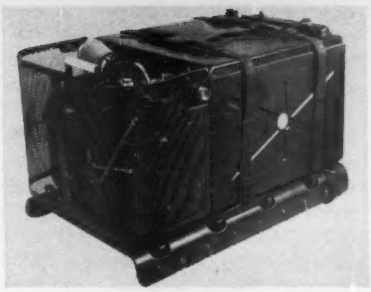

Fig. 4. The General Electric ion-exchange membrane cell. [Courtesy General Electric Company]

The products of the oxidation of the ethane are carbon dioxide (97 mole-percent) and formate (3 mole-percent). Intermittent operation for up to 500 hours has been obtained without any indication of electrode deterioration. Only low current densities (7 amp/ft^2) can be drawn from the cell at reasonable voltages in sustained operation, according to information released by Esso (*20*). Nevertheless, the electrochemical oxidation of hydrocarbons at low temperatures in the Esso cell is a major step toward the final development of practical hydrocarbon-consuming fuel cells.

A complication associated with the use of alkaline electrolytes for cells involving the oxidation of organic compounds is the accumulation of carbonates within the solution. After a brief period of operation, the concentration of the carbonates increases to the point where they precipitate out of solution. Thus, it is necessary to replace the alkaline electrolyte or to remove chemically the carbonates from the electrolytic solution; neither of these steps appears practical from an economic standpoint. The carbon dioxide formed as a product in the oxidation of organic compounds would not accumulate within the solution in the cell if the solution were acid. Considerable question, however, exists as to whether the hydrocarbon anodes or the oxygen cathodes can be operated at appreciable current densities in other than highly alkaline solutions. Another suggestion has been to use a carbonate-bicarbonate electrolyte at temperatures close to the boiling point of the electrolyte. Under these conditions, the carbon dioxide could also be removed from the solution as a gas. With this electrolyte, however, the cells are likely to be limited to relatively low power densities because of kinetic factors and complications associated with mass transport in the solution (*21*).

Alcohol-consuming cells. Many industrial and academic groups both in the United States and in Europe have been working on fuel cells that consume alcohols—particularly methanol. Alcohols can be oxidized electrochemically all the way to carbon dioxide with sufficiently catalytically active electrodes. Most of the alcohol-consuming cells use porous metal oxygen cathodes and operate with concentrated potassium hydroxide as the electrolyte, at 40° to 100°C. In operation on ethylene glycol, Spengler and Gruneberger (*5*) of Ruhrchemie AG (Germany) have reported obtaining 200 amperes per square foot at a cell voltage of 0.75 volt at 80°C, in sustained operation.

The Allis Chalmers Manufacturing Company (*10*) has developed a methanol–hydrogen-peroxide-consuming cell which they have been selling in the form of a demonstration kit (the only fuel cell commercially produced today). This cell uses silver-plated nickel electrodes for the cathodic reaction, involving the reduction of hydrogen peroxide, and platinum-plated nickel for the anodic reaction, involving the oxidation of methanol in a concentrated potassium hydroxide solution. The voltage is quite low (0.3 volt at 60 amp/ft^2), and much of the hydrogen peroxide reacts directly with the methanol without providing useful electrical energy. This cell is recommended for high school students who wish to construct fuel cells because it avoids the use of the relatively complicated porous electrode systems which are required for gaseous reactants.

None of the alcohol-consuming cells presently available appear to have any substantial commercial or military significance, since the carbon dioxide formed as a cell product accumulates within the highly alkaline electrolytic solutions in the form of carbonate, with resulting complications much the same as with the hydrocarbon-consuming aqueous cells. Cells operating with carbon-dioxide-rejecting electrolytes are yet to be developed.

The sodium amalgam-oxygen cell. Sodium metal is ordinarily far too reactive for use directly as an electrode in an aqueous electrolyte. Liquid sodium amalgam, however, is much less reactive and has been used successfully in continuous-feed cells (*22*) with an oxygen

cathode in a concentrated sodium hydroxide solution at temperatures from 20° to 80°C. The reactions are as follows:

$$\text{Amalgamation: } 4Na + 4xHg \rightarrow 4Na(Hg)_x \quad (18)$$

$$\text{Anode: } 4Na(Hg)_x \rightarrow 4Na^+ + 4xHg + 4e^- \quad (19)$$

$$\text{Cathode: } O_2 + 2H_2O + 4e^- \rightarrow 4OH^- \quad (20)$$

$$\text{Over-all: } 4Na + O_2 + 2H_2O \rightarrow 4NaOH \quad (21)$$

The liquid sodium amalgam is allowed to flow down the surface of a vertical steel plate in an arrangement of the type shown in Fig. 5. The oxygen cathode may consist of either a porous carbon electrode or a porous metal electrode, similar to those used in the hydrogen-oxygen cells. In contrast to all of the other systems described previously, this cell makes its own electrolyte. In addition to sodium and oxygen, however, water is required as a reactant. Sea water has been used directly, and successfully, without the removal of any of the mineral constituents prior to its introduction into the cell. The sodium hydroxide produced by the cell reaction can either be discarded directly or used for other chemical processes.

The sodium amalgam-oxygen cell provides a considerably higher voltage (for example, 1.50 volts at 150 amp/ft^2) than any of the other continuous-feed cells described in this article and is capable of operating at power densities approaching those of the Bacon cell. Furthermore, only three-fifths as much oxygen is required per unit energy output as with hydrogen-oxygen cells—a decided advantage in applications where atmospheric oxygen is not available. The sodium amalgam-oxygen cell is also capable of operating at reasonable current densities on air.

The production of electrical power with this system is expensive (of the order of $0.25 per kilowatt-hour) because of the use of sodium. Furthermore, the auxiliary equipment required for the operation of the system is relatively complicated. Some consideration is being given to the use of the sodium amalgam-oxygen cell for military applications. In addition, a possible application exists in the alkali-chlorine industry. At the present time, large quantities of sodium amalgam produced during the electrolysis of brine are allowed to react with water to produce caustic without providing any electrical energy. The use of the sodium amalgam cell makes it possible to produce caustic from sodium amalgam while obtaining electrical energy.

The sodium amalgam-oxygen system was originally developed at Western Reserve University (*22*) in 1955 and has been subsequently worked on by the Union Carbide Corporation and the M. W. Kellogg Company under contract with the U.S. Government.

Biochemical fuel cells. Several groups including the U.S. Geological Survey and Joseph Kay and Company, Inc., are reported (*23*) to be working on biochemical systems as sources of electrical energy in the form of fuel cells. The biochemical fuel cell under development by Fred Sisler of the Geological Survey consists of two sections containing inert electrodes. In the anodic section, in sea water, is a mixture of organic matter (the fuel) and bacteria (a source of enzymes for the catalytic electrochemical oxidation of the fuel). The cathodic section consists of an oxygen cathode. No information is available as to the projected operating characteristics for a cell of this type. The idea of such a fuel cell, however, is quite intriguing since it may provide a means for deriving energy from waste organic matter which cannot be utilized effectively by any other means (for example, corn cobs, sawdust, and even sewage).

Applications

Many applications exist for a reliable, low-cost fuel cell operating on a practical fuel such as oil or natural gas. While definite progress is being made toward the development of such cells, they are not likely to become available in less than 10 years. Of particular significance is the potential use of fuel cells operating on hydrocarbons, or possibly methanol, in automobiles, trucks, and locomotives. If such applications do become widespread, the effect on various industries within the United States would be extreme. The benefits, other than economic, to be derived from such developments include freedom from noise and probably from the obnoxious exhaust gases associated with conventional engines.

Development of central power plants operating with fuel cells as the main source of power appears unlikely for some time to come because of economic factors. The conversion of the low-voltage direct-current power provided by fuel cells to the high-voltage alternating-current power required for distribution is likely to prove expensive in terms of initial investment for the foreseeable future. Furthermore, in the United States fuel cells operating on hydrocarbon fuels are not likely to be competitive economically with more conventional, turbogenerating equipment operating on low-cost coal, even though the efficiency is higher for the fuel-cell system. No fuel cells currently under development appear capable of operating directly on coal.

The only type of fuel cell which is likely to become readily available for nonmilitary use during the next five years is the hydrogen-oxygen cell. Applications for these cells are quite limited because of the relative impracticality of hydrogen as a fuel in many applications. This gas is awkward to store, either cryogenically or as a compressed gas.

The cheapest source of hydrogen presently available is the reaction of coal or hydrocarbons such as natural gas with water. Hydrogen produced in this way, however, usually contains significant amounts of carbon monoxide and carbon dioxide unless somewhat expensive steps are taken to remove these chemicals. With the exception of the General Electric ion-exchange membrane cells, all of the hydrogen-oxygen cells in advanced stages of development have alkaline electrolytes and hence require hydrogen relatively free of carbon monoxide and carbon dioxide to avoid the accumulation of carbonates within the electrolytic solution. While the General Electric membrane cell does not accumulate carbonates, some question exists as to whether the precious metal catalysts in this cell will be progressively poisoned by impurities such as sulfides and carbon monoxide.

Nonmilitary applications for hydrogen-oxygen cells appear to be limited. These cells may find some application as sources of power in such devices as lift trucks and mine locomotives where fumes associated with conventional combustion engines cannot be tolerated and where compressed hydrogen cylinders may be satisfactory as a source of hydrogen for the cells. These hydrogen cylinders could be recharged relatively easily with hydrogen produced chemically or electrochemically. Hydrogen-oxygen cells may also be of significance for power generation in instances where low-cost, relatively pure

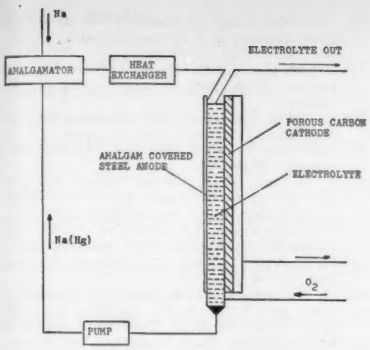

Fig. 5. Schematic drawing of the sodium amalgam-oxygen (*22*).

hydrogen is produced as a by-product of other chemical processes.

A number of military applications are being contemplated for fuel cells at the present time, and this accounts to a considerable degree for the large amount of research and development work in progress on fuel cells in the United States relative to the activity in other countries. These particular applications range from use of the cells in small portable power packs capable of being carried by a single person to use in large power plants for submarine propulsion. Some consideration has been given to the use of hydrogen-oxygen cells for auxiliary power in space vehicles. The hydrogen and oxygen would either be carried cryogenically or produced chemically by reactions involving chemicals of low molecular weight. The practicality of such applications remains to be evaluated.

Closed-cycle operations. Fuel cells are being considered for use as components in various types of closed-cycle systems. In these cycles the cell reactants are regenerated from the cell products. The various methods for regenerating cell reactants may be classified as follows: (i) chemical, (ii) electrochemical, (iii) photochemical, (iv) radiochemical, and (v) thermal. The General Electric redox system is an example of a closed-cycle system involving chemical regeneration.

Electrochemical regeneration is of interest as a means of storing electrical energy. Consideration (*5, 24*) is being given to the use of hydrogen-oxygen cells in such a closed cycle. Water would be electrolyzed in a high-pressure electrolyzer during times of excess electrical power, and the hydrogen gas would then be stored either in tanks or in porous rock strata such as are available in areas of the world where there are exhausted natural-gas wells. When power is subsequently required, the hydrogen would be consumed in hydrogen-oxygen cells. Oxygen can either be stored or obtained from air. The electrolysis operation and the subsequent power generation probably cannot be accomplished with the same cells, although attempts to do this are being made. The efficiency of such an energy storage system is likely to be less than 60 percent because of the relatively large difference between the voltage required to electrolyze water and the voltage of the operating hydrogen-oxygen cells. Such energy storage systems might be of particular interest in applications where the availability of hydroelectric power varies considerably on a seasonal basis because of variations in rainfall, and where the capacity of water-storage reservoirs is inadequate.

The closed cycle involving photochemical regeneration is illustrated by a system in which hydrogen and oxygen required for a low-temperature hydrogen-oxygen fuel cell are produced photochemically by means of solar energy from water derived from the cell. The dissociation of the water with sunlight is relatively inefficient, even with the best known catalyst added to the water to promote photochemical dissociation. The U.S. Government is currently sponsoring the study (*25, 26*) of various photochemical regeneration systems for possible space-vehicle applications. One of the more promising cycles involves the photodissociation of nitrosyl chloride to yield $NO + Cl_2$, which would then be fed to a continuous-feed cell operating on these gases (*25*).

The radiochemical closed cycles are similar to those involving photochemical regeneration, except that the source of radiation is a radioisotope or nuclear reactor. Rosenblum and English of the National Aeronautics and Space Administration (*27*) have considered the use of a hydrogen-oxygen fuel cell with the reactant gases produced by the decomposition of water with a radioisotope such as the alpha emitter polonium-210 ($t_{½} = 138$ days) for space-vehicle applications. In the proposed system, water is first dissociated to yield H_2 and H_2O_2. The H_2 gas is liberated readily from the water in view of its low solubility, while the H_2O_2 in solution is passed into a separate vessel in which it is catalytically decomposed to yield O_2. The H_2 and O_2 are then fed into the fuel cell. The electrolytic solution from the fuel cell is subsequently passed through a radiator to dissipate heat and is then recycled to the radiation chamber. This particular system does not appear to be competitive on a power-per-unit-weight basis with other power sources, such as a solar battery, in space-vehicle applications.

The Union Carbide Corporation is developing a closed-cycle system in which the electrochemical cells operate on H_2 (anodic reactant) and Fe^{2+} (cathodic reactant) generated by the irradiation of oxygen-free acidified ferrous sulfate solution with alpha-rays.

Several types of thermal closed cycles (*28*) involving fuel cells have been proposed for the generation of electrical energy from heat derived from a thermal source such as a nuclear reactor. The most important of these is a cycle in which the reactants for the fuel cell are obtained by heating the products of the cell reaction to a temperature sufficient to produce dissociation. The upper limit for the theoretical thermal efficiency of such a system is set by the Carnot cycle equation (Eq. 1). Advantages which are anticipated for such thermal electrochemical converters are, (i) relatively high efficiency for the conversion of thermal to electrical energy, (ii) a minimum of machinery, particularly of machinery operating in high-temperature environments, and (iii) ultimate simplicity.

Several specific systems have been proposed for the simple thermal dissociation cycle. The one that is receiving the most effort is the Li-H_2 system, originally proposed by the Mines Safety Appliance Research Corporation (*29*). The reactions are as follows:

$$\text{Anode: } 2Li \rightarrow 2Li^+ + 2e^-$$

$$\text{Cathode: } H_2 + 2e^- \rightarrow 2H^-$$

$$\text{Cell: } 2Li + H_2 \rightarrow 2LiH$$

$$\text{Regeneration: } 2LiH \rightarrow 2Li + H_2\uparrow$$

The electrochemical cell is operated at a temperature of approximately 450°C with a fused LiF–LiCl eutectic as the electrolyte. The regeneration of the lithium hydride is accomplished at a temperature of approximately 1000°C. The theoretical upper limit (Carnot) for the efficiency cannot exceed 50 percent; the actual efficiency is likely to be much less. The U.S. Government is currently sponsoring research on this system for possible space-vehicle applications.

Many technical problems, primarily relating to the high operating temperatures, must be overcome before such systems find application.

References and Notes

1. W. R. Grove, *Phil. Mag.* **3**, No. **14**, 129 (1839).
2. K. Kordesch, in *Fuel Cells*, G. Young, Ed. (Reinhold, New York, 1960), pp. 11–22.
3. F. T. Bacon, *Proc. Roy. Inst. G. Brit.* **38**, 186 (1960); ———, in *Fuel Cells*, G. Young, Ed. (Reinhold, New York, 1960), pp. 51–77.
4. K. Bischoff, E. Justi, H. Spengler, *Abhandl. math.-naturw. Kl. Akad. Wiss. Lit. (Mainz)* **No. 1 (1956)**; see also E. Justi, M. Pükuhn, W. Scheibe, A. Winsel, *ibid.* **No. 8 (1959)**.
5. H. Spengler and G. Gruneberg, *Dechema Monograph.* **38**, 579 (1960).
6. See, for example, M. Davies, E. Yeager, M. Clark, F. Hovorka, *J. Electrochem. Soc.* **106**, 56 (1959).
7. In cells with construction of the type shown in Fig. 1, the apparent or superficial area of the anode equals that of the cathode. In this article, current densities are expressed in terms of the superficial area of either the cathode or the anode; they are essentially the same.
8. O. Davtyan, *Bull. Acad. Sci. U.S.S.R., Div. Sci. Technol.* **1946**, 107, 215 (1946); "The Problem of Direct Conversion of the Chemical Energy of Fuel into Electrical Energy," *Acad. Sci. U.S.S.R. Spec. Publ.* (1947).
9. E. Justi, *Jahrb. Akad: Wiss. Lit. (Mainz)* (Steiner, Wiesbaden, Germany, 1955), p. 200.
10. J. Slaughter, Electrochemical Society, 119th national meeting, Indianapolis (1961).
11. L. W. Niedrach, *Proc. Annual Battery Research and Development Conference, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., 13th conf.* (1959), pp. 120–122.
12. W. Carson and M. Feldman, *ibid.*, pp. 111–113.
13. A. Posner, *Fuel* **34**, 330 (1955).
14. D. L. Douglas, in *Fuel Cells*, G. Young, Ed. (Reinhold, New York, 1960), pp. 129–149.
15. E. Gorin and H. Recht, *Chem. Eng. Progr.* **55**, 51 (1959).
16. E. A. DeZubay, Preprints, National Aeronautic Meeting, Society of Automotive Engineers, New York (1960).
17. G. H. Broers and J. Ketelaar, in *Fuel Cells*, G. Young, Ed. (Reinhold, New York, 1960), pp. 78–108.
18. H. H. Chambers and A. D. Tantram, *ibid.*, pp. 94–108.
19. V. Daniel'Bek, M. Mints, V. Sysoeva, M. Tikhonova, *Zhur. Priklad. Khim.* **32**, 649 (1959).
20. "The Fuel Cell: A Footnote on Research," *Esso Research and Engineering Co., Linden, N.J., Spec. Publ.* (1960).
21. K. Williams and D. Gregory, Electrochemical Society, 119th national meeting, Indianapolis (1961).
22. E. Yeager, in *Fuel Cells*, W. Mitchell, Ed. (Academic Press, New York, in press).
23. *Wall Street Journal* (Midwest edition) **1961**, 1, 14 (11 May 1961).
24. J. S. Bone, *Proc. Annual Battery Research and Development Conference, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., 14th conf.* (1960), pp. 62–64; W. H. Podolny, *ibid.*, pp. 64–67.
25. W. McKee, E. Findl, J. Margerum, W. Lee, *ibid.*, pp. 68–72.
26. H. Silverman, W. Momyer, M. Eisenberg, *ibid.*, pp. 72–75; J. W. Eerkins, Preprints, Space Power Systems Conference, American Rocket Society, Santa Monica, Calif. (1960).
27. L. Rosenblum and R. English, "Proc. Seminar on Advanced Energy Sources and Conversion Techniques," *U.S. Dept. Commerce Office Tech. Services Publ. No. P.B. 151461* (1958), vol. 1, pp. 243–253.
28. E. Yeager, *ibid.*, pp. 69–81.
29. R. Shearer, J. Mausteller, T. Ciarlariello, R. Werner, *Proc. Annual Battery Research and Development Conference, U.S. Army Signal Research and Development Laboratory, Fort Monmouth, N.J., 14th conf.* (1960), pp. 76–78.

INSTRUMENTS AND TECHNIQUES

The Cambridge Electron Accelerator

This 6-billion-volt machine will be the world's highest energy electron synchrotron.

M. Stanley Livingston and William A. Shurcliff

By the autumn of 1961, if all goes well, the family of great accelerators will be joined by a new member: the Cambridge Electron Accelerator (CEA). The newcomer differs from the mammoth *proton* accelerators at CERN and Brookhaven in that it will produce high-energy *electrons*. The electron is the lightest of all charged particles and can be accelerated to especially high velocity. In the Cambridge machine the electrons will reach a speed virtually indistinguishable from that of light itself—a speed of 0.999,-999,996 c (c is the velocity of light). A more meaningful measure is the electron energy, which will be 6 billion electron volts (6 Bev)—five times higher than that available from any existing electron accelerator. Another interesting property is the electron mass, which will be increased to nearly 12,000 times the rest mass, or to a value six times greater than the mass of a proton. (*Ponderizer* might be a more descriptive name than *accelerator*.)

This machine will also produce higher intensities than other multi-Bev accelerators. Thanks to the fast cyclic repetition rate of 60 cycles per second, the number of 6-Bev electrons produced per second will be about 6×10^{13}, equivalent to an average current of 1 microampere. Since the product of current and voltage is power, the average power in the electron beam will be 6 kilowatts. With such high electron energy and beam intensity available, experimenters will be able to explore a new range of phenomena in particle physics.

The CEA is jointly sponsored by Massachusetts Institute of Technology and Harvard University and is supported by the U.S. Atomic Energy Commission. Unlike other large accelerators, built in large open areas at the national laboratories, the CEA is located in the heart of a university, in close proximity to the Harvard physics buildings and libraries (Fig. 1). Thus it will be readily available to the faculties and students. Senior staff members of the CEA hold appointments from the universities and cooperate in the research and teaching programs. As one of the major accelerator research facilities of the country, the CEA will be available for use by qualified visiting scientists from other institutions here and abroad.

The operating policies are guided by a joint M.I.T.–Harvard committee composed of administrative and scientific representatives of the two institutions. Detailed planning began in April 1956. Site excavation was started in November 1957, with a ceremony involving a twin-handled shovel jointly wielded by President Julius A. Stratton of M.I.T. and President Nathan M. Pusey of Harvard. A laboratory staff has been assembled, with representatives from many countries. A laboratory report (*1*) summarizes the basic design principles and gives the names of many of the persons who have contributed.

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Particle Physics

The field of research serviced by these giant machines is called "particle physics." It is the study of the properties of the fundamental particles—the protons, neutrons, and electrons of which matter is made—and of the laws of force and particle interaction that make these particles stable and other forms of matter unstable. The concentrated, intense beams of high-energy particles from accelerators are used as probes for studying these properties. At Bev energies the probes are extremely "sharp," capable of penetrating to within collision distances smaller than the dimensions of single particles, and thus able to disclose details of their structure.

At these energies, unstable particles are formed which represent "excited states" of matter, such as the several types of mesons (intermediate, in mass, between electrons and protons) and the several types of hyperons (greater in mass than protons or neutrons). The excess mass of these short-lived states of matter is supplied by the kinetic energy of the bombarding particles. Of great interest, also, are the "antiparticles"; it now appears that each normal particle has its antiparticle, and that matter and antimatter form a symmetrical pattern. A newly created antiparticle, after being slowed down, "annihilates" with a normal twin, and the mass energy of the two particles is transformed into the kinetic energy of the resulting photons or other secondary particles.

Why Electrons?

High-energy electrons can do many things that protons cannot do. One of the basic areas of research in particle physics has been the study of the distribution of mass, charge, and magnetic field inside single particles by scattering electrons from simple targets. In recent years such experiments have been performed with the 0.7-Bev linear accelerator at Stanford University and the 1.2-Bev synchrotrons at Cornell University and at California Institute of Technology. The much higher energy of the Cambridge machine will extend these studies and should improve the resolution; crucial experiments lie just beyond the energy limits of the existing accelerators. One specific goal is the determination of the electric form factor and the magnetic form factor of the proton and the neutron.

Electron scattering experiments are of especially great value since electrons exert—traditionally—only central forces (forces that depend solely on distance of separation and not on orientation). Protons exert central forces and also noncentral forces; the latter depend on the orientation (polarization) of the bombarding particles and the target particles. Since the dependence is complicated and not fully understood, the different, and presumably simpler, evidence from electron scattering experiments should aid significantly in the interpretation of the complex nuclear force.

A beam of 6-Bev electrons is a superlative tool for producing high-energy photons ("bremsstrahlung" x-rays) from any target. This bremsstrahlung radiation is a continuous spectrum extending up to the maximum energy of the electrons. Calculations suggest that one photon of between 5- and 6-Bev energy will be emitted for every ten electrons striking the target. The angle of projection of the photons is limited to a very narrow cone in the forward direction; the angle is so small that the spread amounts to less than one inch in a 100-foot run.

The photon beam can be used for a variety of experiments not possible with proton accelerators. An example is the photoproduction (from targets consisting, say, of hydrogen) of pairs of mesons, hyperons, and other particles. Photoproduction is theoretically simpler to analyze than proton-proton interactions (which also produce particle pairs), since it involves the known electromagnetic field interaction. The several types of short-lived particles, or excited states, will be produced in much greater abundance than is possible at lower energies. The 6-Bev energy is sufficient for production of all known particles, in the form of pairs, except the heaviest—the X hyperon; X particles can be produced singly in alternative processes. Study of photoproduction reactions will add vital new information about the interparticle forces. The secondary particles themselves will have quite high energies and hence can be studied effectively.

Specialists in the field of quantum electrodynamics are eagerly awaiting the results of one particular type of photoreaction—namely, the photo-

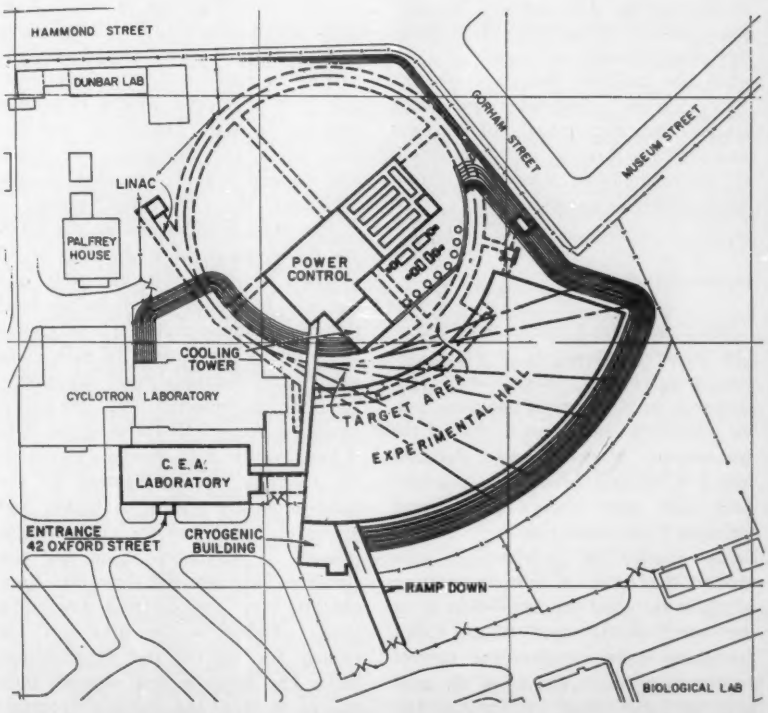

Fig. 1. The general layout of the Cambridge Electron Accelerator. The circular orbit is 236 feet in diameter and is 10 feet below ground level. The experimental hall is as large as a football field.

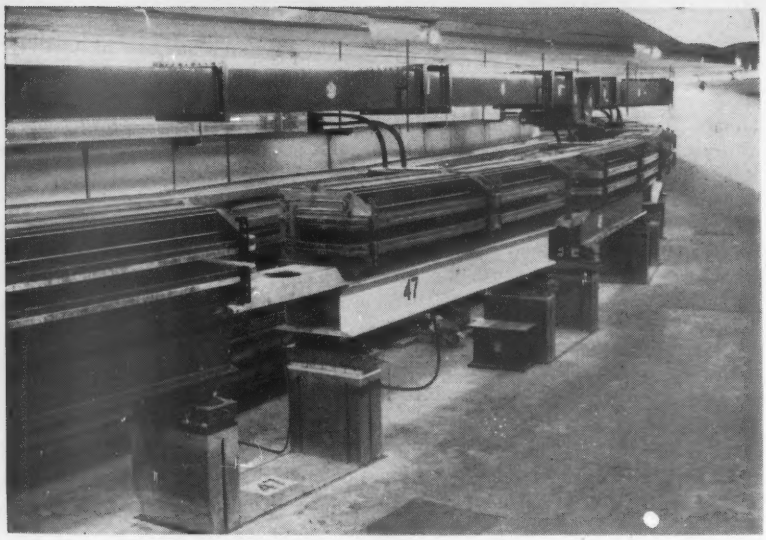

Fig. 2. A portion of the circular array of 48 magnets. Each magnet is 12 feet long and weighs 6 tons. Above the magnets are the radio-frequency waveguides.

production of pairs of positive and negative muons (μ mesons). Experiments performed with existing accelerators suggest that muons are generally similar to electrons (except as regards mass and lifetime) and obey the same quantum electrodynamical laws that electrons obey. The question is: Will this similarity persist even when multi-Bev energies are employed—that is, when the collision distances are less than 2×10^{-14} centimeter and hence are less than the diameter of the electron itself? Is there an energy at which the well-established laws of quantum electrodynamics break down?

Design Principle

The Cambridge Electron Accelerator, like other synchrotrons, operates on the principle of phase-stable synchronous acceleration at constant radius, a principle analogous to that of the synchronous electric motor. Particles follow a circular orbit in a magnetic field and gain energy in varying amounts from radio-frequency electric fields applied at accelerating gaps around the orbit. A particle crossing a gap at the ideal moment—that is, at the "synchronous phase" of the radio-frequency wave—receives the correct acceleration, hence arrives at the next gap at the ideal moment. The momentum of such a particle increases at just the right rate to match the increase in magnetic field strength; thus, the diameter of the orbit remains unchanged. Particles that fall behind the synchronous phase receive less energy and catch up with the synchronous particles; those that lead in phase get more energy and fall back. (Paradoxically, the only way a very fast electron ($v \cong c$) can catch up in phase is to slow down physically. When going more slowly it travels in an orbit of smaller diameter and hence completes one turn in shorter time.) Individual particles oscillate about the synchronous phase; the oscillations are gradually damped and the electrons become "bunched" about the correct phase.

The main components of the CEA are the preaccelerator, the ring of 48 magnets forming a circular orbit, and the radio-frequency system for acceleration. Operation is cyclic, at a frequency of 60 cycles per second. In each cycle a pulse of electrons from the preaccelerator is inflected into the orbit when the strength of the magnetic field is low. As the field strength increases, the electrons are accelerated by the radio-frequency system to higher and higher energy. When the field strength reaches its maximum value and the electrons have attained their maximum energy, they are diverted toward a target adjacent to the orbit (or are ejected for use in the experimental hall). The magnetic field strength then returns to zero, and the cycle repeats. The result is a sequence of short bursts of high-energy electrons. Each group makes about 10,000 trips around the ring in an elapsed time of 1/120 second (0.008 sec); the period of a single revolution is 0.7 microsecond.

The preaccelerator, or linac, produces pulses of electrons of 25-Mev (million electron volt) energy. It is located in a straight spur tunnel that is tangent to the circular tunnel housing the 48 magnets. It emits a pulse (of about 1 microsecond duration) in a slender, well-colliminated beam which is inflected into the orbit by an auxiliary magnet field in one of the spaces between magnets. The auxiliary field is maintained just long enough to fill one turn of the orbit with electrons and is then pulsed off very quickly (0.1 μsec) so as not to distort the orbit of electrons completing their first turn.

The 48 magnets, each 12 feet long, are arranged in a circle 236 feet in diameter (Fig. 2). Each is separated from its neighbor by a 3-foot space, or straight section. The poles of the magnets are not parallel but are slightly wedge-shaped, to provide the nonuniform fields that accomplish the alternating-gradient focusing discussed in a later paragraph.

The feature that makes an electron synchrotron simpler than a proton synchrotron is the extremely high speed of the orbiting particles. In the CEA, the electrons are injected into the orbit with an energy of 25 Mev and a speed of 0.9998 c; consequently, the speed can increase by only 0.02 percent in the subsequent acceleration. Because the speed is so nearly constant, and because the orbit radius changes so little (about 0.3 in.), the accelerator designer may employ a *fixed frequency* radio-frequency system. This permits use of tuned, high-Q radio-frequency cavities which, when excited at the resonant frequency, produce very high accelerating voltages even at relatively low power.

The magnetic field produced by the ring of 48 magnets does not change the energy of the electrons but performs the function of deflecting them into a circular path so that the radio-frequency system can act on them repeatedly, throughout many turns (about 10,000). In a typical turn, the kinetic energy of the electron increases by about 0.6 Mev. If this were the only energy requirement on the radio-frequency system, this system could be of quite modest size and power.

The actual requirement near the end of the acceleration interval is ten times higher than the average required

for acceleration, due to the enormous radiation losses suffered by the electrons. It is well known that whenever a strong magnetic field acts on a very fast electron, accelerating it radially, the electron radiates energy (synchrotron radiation) consisting of a broad spectrum of visible light, ultraviolet, and soft x-rays. The energy lost by synchrotron radiation increases with the 4th power of the electron energy. A 5-Bev electron traveling in an orbit of 90-foot radius (2) loses about 2 Mev of energy per turn, and a 6-Bev electron loses 4.5 Mev per turn. To compensate for such losses the radio-frequency acceleration system must be driven to especially high voltages at the end of the acceleration cycle.

Synchrotron radiation is disturbing in another way: an orbiting electron suffers discrete changes in momentum on emitting photons of synchrotron radiation and begins to oscillate about the normal orbit. The oscillation grows with increasing energy and with time, so that ultimately many electrons would be thrown out of the orbit. This phenomenon sets a practical limit on the energy that can be imparted to an electron by a given synchrotron. With the 1/120-second rise time and the orbit radius chosen for the Cambridge accelerator, the practical energy limit is between 6 and 7 Bev.

Alternating Gradient Magnetic Focusing

The CEA, like the 30-Bev proton synchrotrons at CERN and Brookhaven, uses a magnet system of the alternating gradient, or strong focusing, type, which confines the beam to an orbit of very small cross section. This focusing principle permits use of magnets that are of small size and have modest power requirements. Thus, the magnets can be operated at a high cyclic rate and short acceleration interval. Because this interval is short, the energy loss by synchrotron radiation remains within reasonable limits, and the design of a 6-Bev machine becomes practical.

Of the 48 magnets, 24 have "positive" gradient and 24 have "negative" gradient (Fig. 3). The field gradient results from the wedge-shaped gap between the poles. By curving the sloping pole-face profiles slightly (so that they resemble portions of a rectangular hyperbola), the gradient can be made uniform across the pole face. In a positive-gradient magnet the gap height *decreases*—and field strength increases—with increasing distance from the accelerator center point; hence, an electron traveling at too-great radius is urged back toward the central orbit; such a magnet is said to be radially focusing. In a negative-gradient magnet the gap height *increases* with distance from the center point and the vertical flux lines are slightly curved outward, so they exert a downward force on an electron that is traveling above the ideal orbit and an upward force on an electron that is below this orbit; such a magnet is said to be vertically focusing. The two types of magnets alternate around the ring; and although each type somewhat reduces the focusing effect of the other type, the over-all effect is one of strong focusing in both vertical and radial directions.

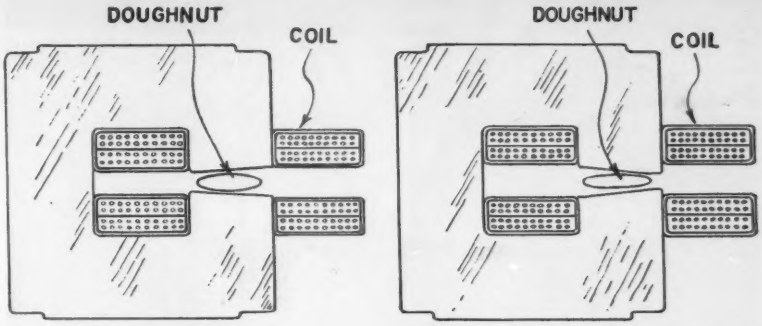

Fig. 3. Cross sections of magnets of (left) the open, vertically-focusing type and (right) the closed, horizontally-focusing type.

The focusing forces cause the electrons to oscillate about the central orbit. Such "betatron" oscillations occur in both the radial and vertical directions. The number of oscillation wavelengths per turn depends on the magnetic gradient and is greater for larger gradients. An integral number of wavelengths per turn is highly undesirable, since it would lead to resonance buiid-up of oscillation amplitudes. Magnets are designed, and gradients chosen, so that the number of wavelengths per turn stays between integral values during the entire acceleration interval. The CEA magnets were designed so that the magnetic field increases (or decreases) by about 10 percent per inch of displacement across the pole face; this gradient leads to a figure of 6.4 for the number of betatron wavelengths per turn, for both radial and vertical oscillations.

The magnets must be precisely aligned around the circular orbit in order to minimize oscillation amplitudes. Alignment errors must be confined to about ± 0.005 inch in the vertical and ± 0.01 inch in the radial coordinate. Firm foundations are required, and also precise adjustment mechanisms and accurate surveying techniques. The magnets rest on heavy girders supported on precision jacks and traverse mechanisms; these rest on piers supported by piles driven deep into the gravel subsoil and mechanically isolated from the rest of the building.

Each magnet consists of 6 tons of die-stamped C-shaped laminations, bonded together into blocks and assembled on a girder 12 feet long. The average magnetic gap length (at the central orbit) is 2 inches, and the poles are only 6½ inches wide. The necessary magnetic uniformity (better than ± 0.5 percent) was achieved by shuffling the laminations prior to bonding and by assembling them with high precision. A typical tolerance is ± 0.001 inch.

The magnet excitation coils are of stranded copper and contain tubes in which cooling water circulates. Each magnet is equipped with "pole face winding" systems which make it possible to make minor corrections to the

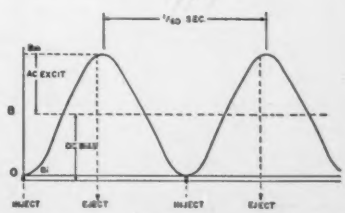

Fig. 4. Wave form of magnetic field strength resulting from the full-biased excitation current. The cycle period is 1/60 second, and nearly half the period is devoted to actual acceleration of electrons.

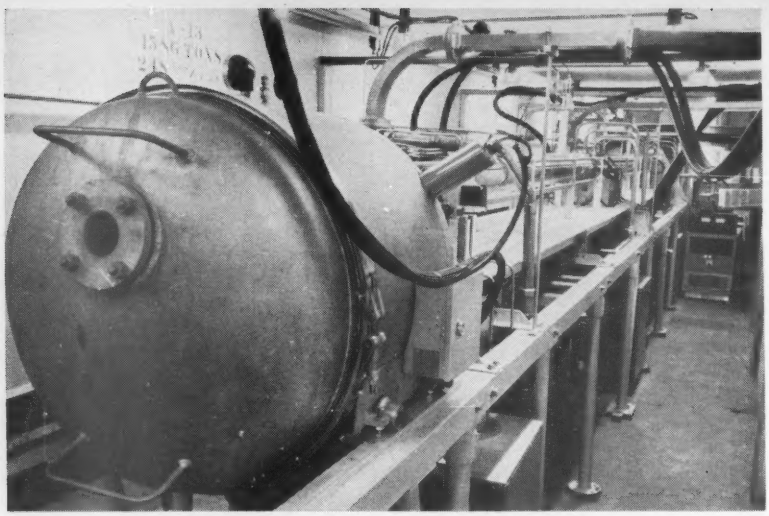

Fig. 5. The 25-Mev linear preaccelerator, which accelerates the electrons from a standing start to a speed of 0.9998 c in a path length of 25 feet. The electrons then enter circular orbit tangentially.

field gradient and to the field itself at the time (near injection) when the field strength is low and remanent fields are appreciable.

One of the unique engineering features of the accelerator is the magnet power supply. This consists of a massive resonant circuit driven by an electronic self-excited oscillator. The power dissipated in the circuit amounts to 1000 kilowatts, and the peak value of circulating power exceeds 100,000 kilovolt-amperes. Electrical engineers have been intrigued by this application of electronic principles to such a large alternating-current power supply.

The current in the magnet excitation coils has a full-biased sinusoidal wave form, as indicated in Fig. 4. It varies from zero to maximum and back again 60 times a second. At the time the preaccelerated electrons are injected into the ring, the excitation current and the magnetic field (then about 30 gauss) are increasing slowly. Eddy-current distortion of the field is small at this critical time, and the efficiency of acceptance of the injected electrons is high. The acceleration rate is greatest when the exciting current is half-maximum. When the current has nearly reached a maximum, the rate of increase of field is again small and the time interval for beam utilization at approximately constant energy is conveniently long.

The full-biased current can be considered as the superposition of a direct current (420 amperes) and an alternating current (300 amperes, root mean square value). The direct current is supplied by a low-voltage ignitron-rectifier system. The alternating current is supplied by pulsing a high-voltage direct-current source.

The resonant alternating-current circuit consists of the ring of 48 magnets (connected in pairs), 24 banks of capacitors, and a ring-shaped energy-storage inductor with 24 identical windings. Cabling connections form a series circuit through the magnet coils and inductor windings, with the capacitor banks connected across the inductor windings. Thus there are 24 subunits in series, each resonant at 60 cycles per second. The direct-current bias current provided by the low voltage supply is introduced at the geometrical and electrical center of one of the inductor windings and traverses all magnet coils and inductor windings in series. A key feature of the circuit is that the currents in all 48 magnets are identical, and consequently the magnets are powered with equal amplitude and phase.

The pulses providing the alternating-current power are fed to the circuit through a distributed set of primary windings around the inductor cores. The pulses are obtained by firing an ignitron in the high-voltage direct-current supply; the ignitron closes the circuit momentarily and sends a pulse of power through the primary from a storage capacitor. The timing signal for pulsing the ignitron is taken from a chosen phase of the circulating power in the main resonant circuit. The timing is such that the pulses occur when the magnet excitation current is decreasing; hence, the pulses do not disturb the smooth rise in field during the acceleration interval.

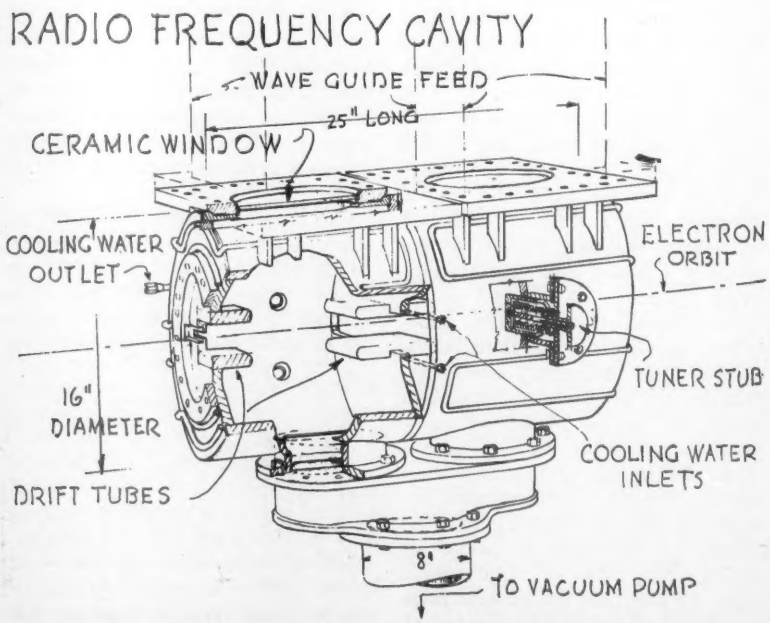

Fig. 6. One of the 16 radio-frequency cavities. The electrons travel along the horizontal axis of the cavity's two resonant chambers and are accelerated by the intense electric fields in the chambers. The fields are supplied by waveguides 18 inches wide (not shown) and air-tight ceramic windows.

Injection

The 25-Mev preaccelerator is a microwave waveguide linac of the traveling-wave type and operates at a frequency of 2855 megacycles (Fig. 5). It consists of two 10-foot sections of S-band, iris-loaded waveguide, each powered by a pulsed Klystron tube of 5-megawatt peak pulse rating. Electrons are emitted from an oxide-coated cathode and pulsed by a 200-kilovolt modulator; they traverse a pre-buncher cavity tuned to the 2855-megacycle frequency, then pass along the two waveguides. The emerging beam has a peak pulse intensity of 150 milliamperes; the beam diameter is 0.4 inch, the angular spread is 0.04 degree, and the energy spread is ± 1.5 percent.

The modulator is triggered by a signal derived from the increasing magnetic field in one of the 48 magnets; triggering occurs when the field strength reaches the value (about 30 gauss) appropriate to 25-Mev electrons. The pulse is of 1-microsecond duration, sufficient to fill the circular orbit of the synchrotron. The preaccelerated beam enters the synchrotron ring almost tangentially at one of the field-free spaces between magnets. There the beam is deflected about 3 degrees (by a weak magnetic field) so as to join the synchrotron orbit smoothly. The deflecting magnetic field is produced by a short pulse of current in a set of specially shaped windings; it is cut off just before the inflected electrons complete one turn around the orbit.

Radio-frequency System

The acceleration system consists of 16 resonant radio-frequency cavities (Figs. 6 and 7) connected by waveguide links to form a circular loop 240 feet in diameter. The cavities operate in phase synchronism, achieved by tuning them and also the waveguide links to the frequency of 475.83 megacycles. The system of resonant cavities and waveguide links constitutes a closely coupled, high-Q, series-resonant circuit which is unique in radio-frequency engineering. It is perhaps the most extended system of high-Q resonant circuit elements operating in a single mode that has ever been built.

Each cavity consists of two half-wave resonators and includes re-entrant drift-tube electrodes forming two 8-inch gaps across which the radio-frequency potential is developed. Thus, the orbiting electrons experience 32 accelerations per turn. The cavities are formed of thick plates and cylinders of high-conductivity copper, brazed to form vacuum-tight chambers. Each cavity is 16 inches in diameter and 24 inches long and is built to very close tolerances. An adjustable tuning stub is mounted in the side of each resonator unit. The radio-frequency power is fed to the cavity through two alumina ceramic vacuum windows installed on the side (upper surface) of the cavity and traverses the two half-wave resonators within the cavity. At peak power the voltage across each resonator gap is 200 kilovolts. Cooling water circulates within the heavy walls and is thermostatically controlled to maintain constant cavity dimensions and hence constant resonant frequency.

The waveguides, of standard rectangular type, 18 inches wide, are formed of welded aluminum sheet and flanges. In each link there are a thermal expansion "choke" joint and two phase-shifters for adjusting the electrical length of the link. The radio-frequency power is fed from an amplifier in the power building by way of a radial run of waveguide which joins the main loop at a T joint.

Since the radio-frequency system includes 48 tuned components (32 half-wave resonators and 16 waveguide

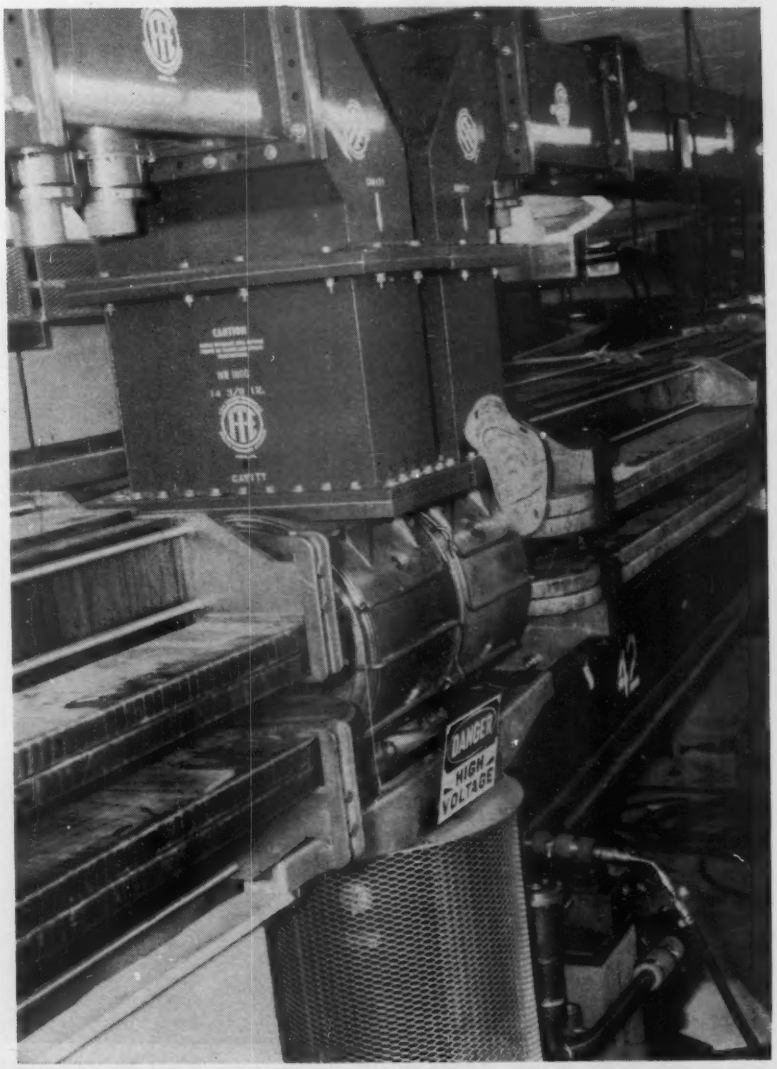

Fig. 7. A radio-frequency cavity in place between two magnets. Above the cavity are the radio-frequency waveguides. Below, suspended from the cavity, is one of the 48 high-vacuum pumps.

links), there are at least 48 possible modes of oscillation. Only one of these modes provides identical phases in all cavities, a condition essential for acceleration of electrons. This mode is spaced from its nearest neighbors (in frequency) by about ten bandwidths and can be selected by precise tuning of all components.

The 475-megacycle power supply consists of a power amplifier (transmitter) employing a high-frequency "superpower triode" as the output stage. Peak power output, occurring at the end of the acceleration interval, is 400 kilowatts; the average power for the duty cycle required in this application is 80 kilowatts. Frequency is determined by a master oscillator which provides excitation for the transmitter. The transmitter is modulated so as to provide about 20 kilovolts per resonator gap (320 kilovolts per turn) at the start of the acceleration interval and 200 kilovolts per gap (6 megavolts per turn) at the end of the cycle, the large increase being necessitated by the rapidly increasing radiation losses experienced by the orbiting electrons.

Vacuum System

The vacuum chamber inside which the beam circulates consists of 48 slender tubes which fit between the poles of the 48 magnets and connect the 16 radio-frequency cavities and 32 other vacuum manifolds occupying the spaces between magnets. Beneath each cavity and manifold is a high-vacuum pump and also a rough-vacuum pump for initial pump-down.

The vacuum chambers have an oval cross section of about 1½ by 5½ inches and are formed of nonmagnetic stainless steel tubing slotted at ½-inch intervals to minimize eddy currents that could distort the magnetic field. An external coating of Fiberglas cloth and epoxy resin seals the slots and provides a vacuum-tight coating. The slots are narrow so that the interior surface is mostly steel, which minimizes evolution of vapor and protects the resin from damage by the intense synchrotron radiation.

The high-vacuum pumps are of the recently developed high-voltage, titanium-discharge type. The discharge between titanium electrodes ionizes the residual gas, and the sputtered titanium acts as a "getter" for the ions that strike the pump walls. The pumps are electronic, without moving parts or objectionable vapors. Metal gaskets are used throughout the vacuum system, and all components are carefully cleaned and baked at elevated temperatures under vacuum. When the initial pump-down is complete, the rough-vacuum pumps are shut off and the titanium pumps continue to operate, maintaining high vacuum in the totally sealed system. The operating pressure of about 1×10^{-6} millimeters of mercury is low enough so that scattering of the orbiting electrons by residual gas in the chamber is negligible.

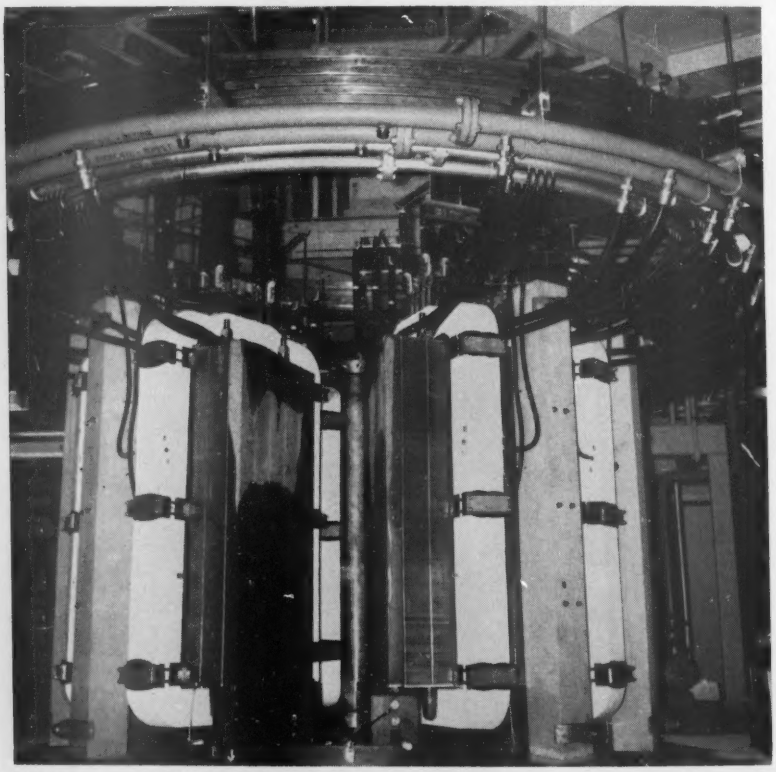

Fig. 8. The 60-ton toroidal inductor for the magnet power supply system (in this photograph one core block and one excitation coil have been removed). The peak energy storage of the inductor is 600,000 joules.

Laboratory Arrangements

The circular tunnel is located underground, with the orbit 10 feet below ground level. Concrete and earth fill (6 to 15 feet thick) over the tunnel shield the above-ground areas from high-energy secondary or scattered radiations. The main power supplies (Fig. 8) are in a central power building connected to the ring by four radial tunnels. One portion of the circular tunnel is widened to provide room for targets, magnets, and other equipment needed for producing, analyzing, and focusing emergent beams. Outside this area is a large experimental hall, separated by a thick shielding wall of iron-ore-loaded concrete blocks. Beams of electrons, photons, and secondary particles can be brought through small channels in this wall into the experimental hall for research experiments.

The experimental hall is larger than a football field and is provided with electrical power, cooling water, a 40-ton traveling crane, and other features. The apparatus used for experiments will be assembled along the trajectories of the emergent beams, from six or more alternate target locations in the ring. Several experiments can be set up and carried out, simultaneously or sequentially, while new experiments are being prepared.

The large pieces of equipment required for experiments include analyzing and focusing magnets, spectrometer mounts for studies of angular distributions, target assemblies of special types, a large hydrogen bubble chamber, and a wide variety of other items. Each experiment will require specially de-

signed shields of dense concrete, iron, and lead. In many cases the output data from electronic counters or other apparatus will be transmitted to data-processing electronic computers in the laboratory building, for analysis and recording. A large cryogenics plant for liquefying helium is being built; a separate helium expansion engine will be mounted near the hydrogen bubble chamber, for maintaining low temperature there. Cold helium gas will be used to cool various special targets of hydrogen and deuterium.

Targets located in a straight section can be placed just outside or inside the beam orbit, and the beam can be diverted against the targets by pulsing special magnets or by turning off the radio-frequency acceleration at the peak of the cycle. High-energy photons are projected forward from such a target in a sharply defined tangential beam. Charged secondary radiations, such as mesons or hyperons produced in a target, can be focused and analyzed magnetically and can pass through other channels in the main shielding wall. Single-beam pulses can be directed at one target (for instance, in a bubble-chamber experiment) and other pulses can be directed at a target serving a different experiment.

In other experiments an emergent beam of 6-Bev electrons will be used. Special magnets located just inside the orbit at chosen straight sections can be pulsed to jolt the electrons out of the orbit into a well-defined emergent beam. This beam will traverse a vacuum pipe through the shielding wall and will be focused by magnetic lenses onto a target in the experimental hall.

A detailed discussion of the experiments planned is beyond the scope of this account. Scientists from M.I.T. and Harvard, as well as from other nearby universities, are actively engaged in designing experiments that should go far toward exploiting this new energy range in the field of particle physics. No effort is being spared to have the necessary equipment and instruments ready for use when the accelerator is completed.

Notes

1. CEA staff report No. CEA-81 (1 Aug. 1960).
2. Although the average radius of the CEA orbit is 118 feet, the radius of a path segment between the poles of a magnet is shorter—90 feet. In the field-free spaces between magnets the path is straight.

INSTRUMENTS AND TECHNIQUES

Defocusing Images To Increase Resolution

Resolution of two luminous particles is improved by defocusing the microscope or telescope.

Harold Osterberg and Luther W. Smith

Consideration of the distribution of energy density in the diffraction image of two unresolvably small, self-luminous particles led us to expect that a marked increase in the lateral resolving power of a microscope or telescope should occur in appropriately selected out-of-focus image planes. This expectation has been confirmed experimentally. In order to obtain an appreciable advantage, the instrument must be adjusted far out of focus, and thus the appearance of two neighboring concentrations of energy density in the blurred image of two self-luminous particles has, no doubt, either been ignored or considered spurious by many observers.

Particles that are viewed by means of the light that they scatter or cause to fluoresce act, in effect, as self-luminous particles. Particles in a dark-field microscope scatter light into the objective and tend to act almost as though they were self-luminous. In fact, under certain conditions of illumination, particles appearing against dark backgrounds closely imitate self-luminous particles. These conditions of illumination exist in interference microscopes, in which destructive interference between the direct and the reference beams renders the background practically dark. Conclusions with respect to the out-of-focus states of self-luminous particles apply, therefore, with minor modifications, to suitably illuminated non-self-luminous particles.

The Airy unit is used as the unit of linear measure in the following discussion. The Airy unit r_a is defined by

$$r_a = 0.61\,\lambda/\text{N.A.} \qquad (1)$$

where λ and N.A. denote wavelength and numerical aperture, respectively. Distance r_a refers to either the object space or the image space, according to whether N.A. is the numerical aperture of the object space or of the image space of the objective. The numerical aperture with respect to the object space is ordinarily $|M|$ times the numerical aperture with respect to the image space, where M denotes the magnification ratio of the objective.

According to Rayleigh's criterion, two particles are resolved when their separation equals or exceeds one Airy unit. In order that two like particles shall be separated by one Airy unit, their effective radius must not exceed one-half Airy unit. We shall see that it is possible experimentally to resolve two like particles having the separation 0.58 Airy unit. The effective radius of such particles can exceed one-fourth Airy unit only slightly. Such particles are unresolvably small from the viewpoint of diffraction theory.

The family of curves of Fig. 1 shows how the distribution of energy density $I(W)$ in the diffraction image of a single self-luminous particle varies with W for a series of out-of-focus states that are most conveniently and completely specified by the parameter ψ. The variable W is the distance in Airy units from the center of the diffraction image, and

$$\psi = \pi \rho_m^2 z/\lambda \qquad (2)$$

where z denotes the out-of-focus distance in the image space and ρ_m denotes the numerical aperture of the objective with respect to its image space. When $\psi = 2\pi$, the eyepiece has been de-

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focused by an amount z such that the center of the diffraction image has become dark.

The energy densities $I(W)$ have been normalized so that $I(W)$ equals 1 at $W = 0$ for the sharply focused state $\psi = 0$. Decisive changes in $I(W)$ occur when ψ exceeds π. The energy content at the diffraction head ($W = 0$) diminishes rapidly with ψ, and, as would be expected, the energy content of the diffraction rings increases with ψ. However, the radius of the central bright spot decreases markedly with increasing ψ. If, indeed, one ventures to extend Rayleigh's criterion to the location of the first minimum for the curve $\psi = \pm 3\pi/2$, two particles would be resolved when their separation is only 0.53 Airy unit. This rough prediction is not far from correct.

The curves of Fig. 1 have been computed by an excellent method conceived by Guy Lansraux (*1*). His notation has been kept, for the convenience of readers who may wish to refer to his article in the *Revue d'optique*.

The graphical method whereby the curves of Fig. 1 have been utilized to obtain information about the combined energy density $I(W)$ in the image of two self-luminous particles is illustrated in Fig. 2 for the case in which the particles are separated by 0.7 Airy unit. The centers of the geometric images of the particles are located at $W = 0$ and $W = 0.7$. Because the two self-luminous particles radiate independently, they produce, about the points $W = 0$ and $W = 0.7$, the independent distributions plotted as the dashed curves A and A' in the sharply focused plane for which $\psi = 0$. Addition of the ordinates of curves A and A' amounts to adding the energy densities due to the two particles and produces the corresponding curve A″ for the designated focal state $\psi = 0$. Similarly, the combined energy density $I(W)$ of curve B″ for the focal states $\psi = \pm 5\pi/4$ is obtained by adding the ordinates of curves B and B'. In order to form a better comparison of the physical processes involved, the curves A and B have been normalized separately so that $I(W) = 1$ at W = 0. This normalization is equivalent to using a brighter source of light for the focal states $\psi = \pm 5\pi/4$.

Two like particles having the separation 0.7 Airy unit are not resolved in the sharply focused image plane for which $\psi = 0$ (curve A'') but *may* be resolved in the out-of-focus planes for which $\psi = \pm 5\pi/4$ (curve B''). It should be observed that curves A and B practically coincide over a marked distance from the diffraction head at $W = 0$ but that curve B has become significantly higher than curve A near $W = 0.7$. It is this increase in the energy content of the outer portion of the out-of-focus curves B and B' relative to curves A and A' that accounts for the formation of the maxima near $W = 0$ and $W = 0.7$ of curve B''. In this way, the graphical study of a variety of out-of-focus cases showed that the increased energy content of the outer portions of the diffraction image of one particle enhances the probability of resolving two particles.

The curves of Fig. 3 were determined after the manner of curve B'' of Fig. 2, so as to illustrate in a systematic manner how the resolving power for two particles depends upon the focal parameter ψ. Consider, for example, the curve for which $\psi = \pm 3\pi/2$. The centers of the geometrical images of the two particles fall at $W = 0$ and $W = 0.53$ Airy unit. The corresponding values of energy density are marked P and P', respectively, with the point P' designated by the circle. The value of the energy density at the midpoint between the geometrical images is marked C and designated by the triangle. Let $I(P)$, $I(P')$ and $I(C)$ denote the energy densities $I(W)$ at the points P, P', and C, respectively. The separation P to P' has been determined so that, approximately,

$$\frac{I(P) - I(C)}{I(C)} = \frac{I(P') - I(C)}{I(C)} = 0.01 \quad (3)$$

When $\psi = \pm 3\pi/2$, the contrast condition of Eq. 3 is met by choosing the separation P to P' as 0.53 Airy unit.

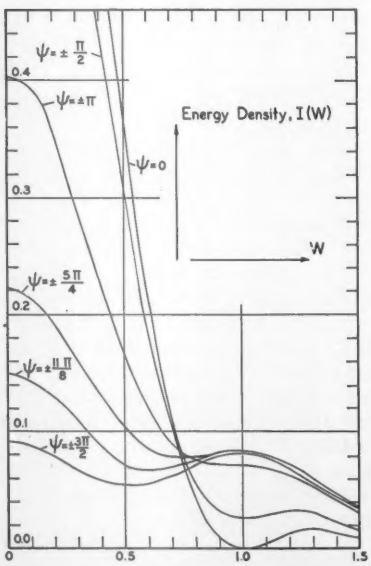

Fig. 1. Plot of the distribution of energy density $I(W)$ against W, the distance in Airy units from the center of the diffraction image of a self-luminous particle for the indicated values of the focal parameter $\psi = \pi \rho_m^2 z/\lambda$. The objective is assumed to be of the idealized Airy type with respect to the sharply focused image plane for which $\psi = 0$.

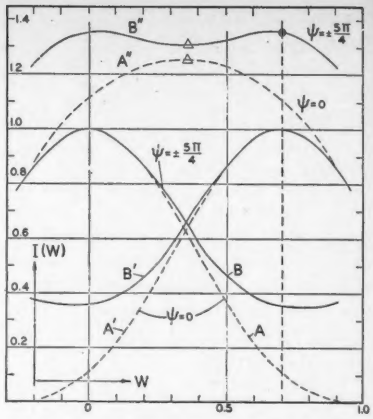

Fig. 2. Plots illustrating how the energy density $I(W)$ in the image of two like particles is determined graphically from the distribution of energy density in the image of one of the particles. The dashed curves pertain to the sharply focused image for which $\psi = 0$. The combined energy density in curve A″ is the sum of the ordinates of curves A and A' for two particles separated by 0.7 Airy unit.

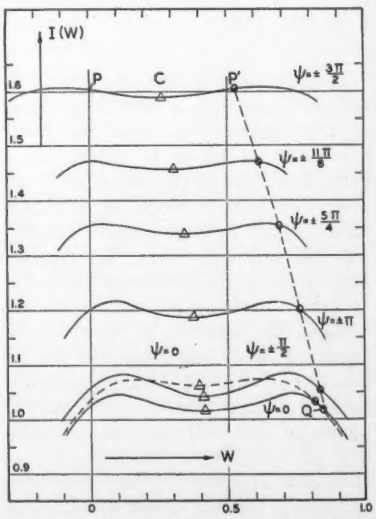

Fig. 3. Plot of distributions of energy density $I(W)$ in the image of two particles for the indicated values of the focal parameter ψ. For each value of ψ the separations P to P' have been determined in accordance with Eq. 3 of the text.

Similarly, all of the curves drawn as solid lines in Fig. 3 have been determined for separations P to P' of the particles in accordance with Eq. 3.

The broken curve belonging to the in-focus state $\psi = 0$ is included for comparison and reference. For this curve the separation of the particles is 0.81 Airy unit—a separation that has been judged resolvable (presumably in the state of sharpest focus) by many observers. Comparison of the curves of Fig. 3 shows that contrast in the image of the two particles equals or exceeds that for the broken curve in the focal state $\psi = 0$. Actual contrast in the diffraction image is usually better than indicated by the fixed value 0.01 of Eq. 3, because the maxima do not ordinarily occur at points P and P'—that is, at the positions of the geometrical images.

Using Eq. 3 as the criterion for resolution, one obtains the broken curve through the points from P' to Q for the corresponding limits of resolution as a function of the focal parameter ψ. For example, with $\psi = \pm 11\pi/8$, this limit of resolution becomes 0.62 Airy unit. Examination of the curve for $\psi = \pm 11\pi/8$ of Fig. 1 shows that the first minimum falls near 0.62 Airy unit, so that one is tempted to invoke Rayleigh's criterion as the practical equivalent of the criterion of Eq. 3. However, this extended notion of Rayleigh's criterion is not in good agreement for ψ values in the range $0 \leqq |\psi| \leqq \pi$.

The first experimental verification of increased lateral resolution by defocusing was performed with a microscope in the following manner. The substage condenser of a microscope was replaced by an oil immersion objective that served to image the bright disk of a 2-watt zirconium arc with demagnification of about 100. This image was formed in the oil film between two cover plates at the stage and was doubled by placing a Wollaston prism between the arc and the objective. Since neither a polarizer nor an analyzer was employed, the doubled image of the zirconium arc served, in effect, as two self-luminous particles. These "particles" were projected by a 5× objective having a low, fixed numerical aperture determined by the interposition of a suitable diaphragm. The resulting image could be viewed through a focusable eyepiece or could be photographed. Movement of the Wollaston prism along the optic axis of the system permitted continuous adjustment of the separation of these "self-luminous particles" at the rear focal plane of the oil immersion objective.

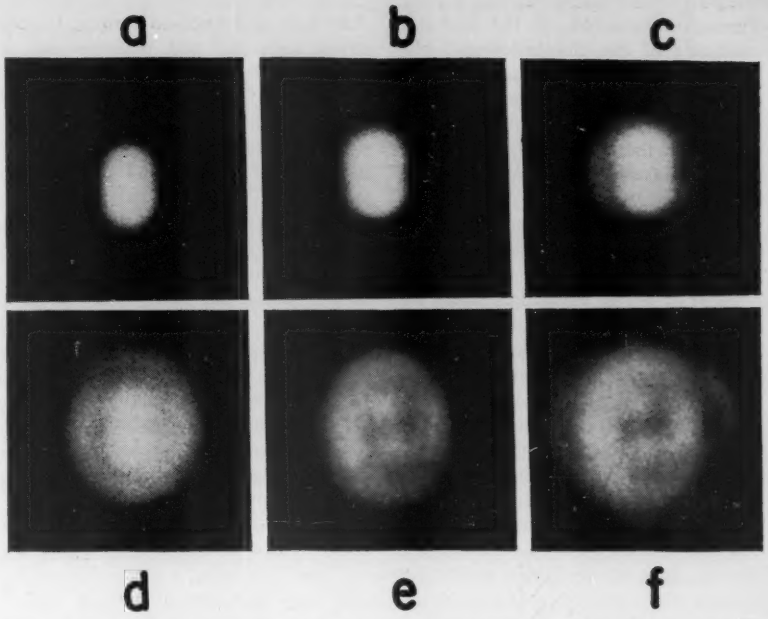

Fig. 4. Photographs illustrating how increased lateral resolution is obtained by defocusing. The distance out of focus is increased progressively from the sharply focused photograph *a* to the most blurred photograph *f*. The two particles are resolved in the blurred photographs *d*, *e*, and *f*, but not in the sharply focused image plane of photograph *a*.

The aperture diaphragm at the 5× objective served also to reduce the numerical aperture of the whole system and thus to avoid aberrations, except for that due to defocus. An interference filter confined the light to a narrow band at 5461 angstroms.

Increased lateral resolving power resulted from moving either the 5× objective or the eyepiece along the optic axis. Motion of the eyepiece is theoretically the preferred method of defocusing, because the numerical aperture of the 5× objective acting as the imaging lens is then undisturbed. In the photographs of Fig. 4 (*a* to *f*), the separation of the two particles was fixed at a value decisively smaller than the limit of resolution in the sharply focused plane (Fig. 4*a*). In photographs *a* to *f*, the amount of defocus is increased progressively up to a point for which $|\psi| < 2\pi$. Although photographs *e* and *f* exhibit much blur, the two particles have become well resolved.

More quantitative observations were made by means of the telescopic arrangement shown schematically in Fig. 5. Stopping the N.A. of the telescope objective down to about 0.0063 made it possible to control and measure the separations between pinholes P_1 and P_2. Distances d_1 and d_2 were about 6 meters and 30 centimeters, respectively.

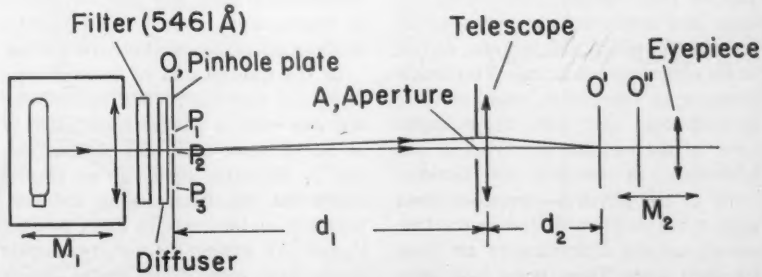

Fig. 5. Diagram of the telescopic arrangement for observing the improvement in lateral resolution of pinholes P_1 and P_2 in out-of-focus image planes. Motion M_1 of the H-4 mercury lamp and pinholes served as fine adjustment of the object distance d_1. Motion M_2 altered the location of the focal plane O" of the eyepiece with respect to the fixed focal plane O' of the image of O. P_3 is an auxiliary pinhole.

Through motion M_1 of the assembly consisting of the illuminator and pinholes it was possible to adjust the N.A. of the telescope, and hence the separation of the pinholes, in a continuous manner to the desired value (in Airy units). Pinhole P_3 was included as a control and was located many Airy units from the tightly separated pinholes P_1 and P_2. The image of pinhole P_3 served, for example, to indicate whether or not $|\psi|$ equaled 2π, since the center of the diffraction image of an unresolvably small self-luminous particle becomes dark in the out-of-focus plane associated with $|\psi| = 2\pi$.

Qualitatively, the parfocal images of the double pinholes resembled the parfocal images of the zirconium arc in the microscope experiment. In one quantitative experiment, the separation of particles P_1 and P_2 was adjusted to 0.58 Airy unit, and resolved readily. In this experiment, the two pinholes had a diameter of 0.142 millimeter and a separation, from center to center, of 0.606 millimeter. Distance d_1 (Fig. 5) was 6032 millimeters, and the diameter of aperture A was 3.84 millimeters. Determined attempts to learn how nearly one can approach the limit 0.53 Airy unit of Fig. 3 were not made, since it was felt that a significant determination of an actual limit would require great care.

In an interesting set of preliminary experiments with the microscope arrangement, a marked amount of spherical aberration was added artificially to the 5× objective. It was found that this addition further increased the lateral resolving power, provided that the defocusing was performed on the "cooperative" side of focus.

When pinholes P_1 and P_2 of Fig. 5 were replaced by narrow slits, separations down to 0.73 Airy unit were resolved in the plane of sharpest focus. Defocusing improved lateral resolution of the two slits only slightly. The resolvable separation was decreased only from 0.73 to 0.71 Airy unit. It is noteworthy that the observed in-focus limit of 0.73 Airy unit practically coincides with the physical limit of resolution given by Osterberg (*2*) for two like slits in an opaque background for the case in which the numerical aperture of the substage condenser of a microscope is set equal to the numerical aperture of the objective.

References

1. G. Lansraux, *Rev. opt.* **26**, 24, Eqs. 26–32 (1947).
2. H. Osterberg, *J. Opt. Soc. Am.* **40**, 295, Fig. 9 (1950).

INSTRUMENTS AND TECHNIQUES

Radio Telemetering from within the Body

Inside information is revealed by tiny transmitters that can be swallowed or implanted in man or animal.

R. Stuart Mackay

It is rather inconvenient to swallow a physician. However, it is quite possible to swallow, or otherwise implant in various body cavities, measuring devices and miniature radio telemetering transmitters which will perform certain of his observation functions. This article attempts to summarize some of these developments and uses as examples some of the methods employed in one laboratory. In the first few sections, some of the physical aspects of these devices are mentioned, and in the last, some examples of application are given for such units. These units have been called endoradiosondes and are so termed here. They are important in studies of human beings because they leave the subject in a relatively normal physiological state, and they are at least as important in animal studies, where discussion and cooperation are lacking.

In the transmission of internal data there are essentially four possibilities: one can build a passive transmitter or an active transmitter, and one can employ a magnetic dipole or an electric dipole (in the latter, using the conductivity of the body to carry out the signal). All except the passive electric dipole have been demonstrated. There seems no adequate reason to expect the optimum carrier frequency to be the same in any two of the methods. Skin depth gives a rough hint of frequency but can be misleading; more tests are needed if minimum energy units are desired. In general, these transmitters have been made to work in the frequency range of ½ to 10 megacycles. As in nuclear resonance experiments, passive magnetic transmitters (in which a resonant circuit alone is swallowed) can work either by absorption or by emission, and the best frequency is probably the same in either case. Physiological variables which can cause a change in reactance of a transducer lend themselves to passive as well as active transmission. Almost any system of modulation other than simple amplitude modulation is suitable in any of the methods. Transmitters whose power is induced in the capsule at one frequency or time and reradiated by an active transmitter at another do not involve any different concepts. Nonradio transmission methods, such as monitoring pressure by observing the size of an ingested balloon with ultrasound or x-rays, are not considered here.

Passive Transmission

In passive transmitters the capsule carries no power source but only a resonant circuit whose characteristic frequency is sensed from outside. This frequency is altered by some reactance whose magnitude changes in response to changes in pressure, temperature,

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voltage, and so on. This was probably the first method tried (*1*), and it still seems the most useful for extended experiments. For brief experiments, it is not certain that passive techniques are best, especially in view of the availability of small, low-power systems involving tunnel diodes or transistors, and of noise-reducing techniques for receivers.

These procedures can be implemented either by frequency-sensitive absorption or by re-emission. An example of the former is the use of a sweeping grid-dip meter to sense the resonant frequency of an ingested tuned circuit (*1*). Increased sensitivity seems to result if the functions of transmission and reception are, instead, separated by feeding a coil on one side of the subject with a cyclically varying frequency in the right range and displaying the output as a function of frequency on an oscillograph fed by a coil on the other side of the subject. Bridge techniques can be used to eliminate much of the steady signal arriving at the second coil.

In the emission method, one observes the ringing frequency of the ingested tuned circuit following application of a short pulse from outside. This input pulse must be a small radio-frequency pulse, so the tuned circuit will show a reasonable scattering cross section; that is, there is no value in having the energy spectrum extend to zero frequency, as it does with either a steady pulse or delta function. As in certain nuclear resonance experiments, in principle it is possible to orient the transmitter and receiver coils perpendicularly so that there is no direct coupling between them except by way of the tuned circuit. Some pressure observations with the emission method have been reported (*2*). It has been suggested that the activity of gastric juices might be studied through the closing of a contact by the digestion of a piece of meat and transmission of this two-valued variable by ringing or nonringing in a paralleled quartz crystal (*3*).

A small coil outside the body gives a rather weak signal because the signal can decay with the sixth power of the distance. If larger coils are placed around the subject, generalization is more difficult, and results are best predicted on the basis of transformer theory. If the tuned circuit is not fairly large and aligned for maximum coupling, then the signal can rapidly become unreliable. Brief attempts were made to cycle between several external antenna coils by using mercury contact relays, but the perfection of transistors made the investigation of active transmitters seem attractive (*1*). Several workers throughout the world independently began such investigations at approximately the same time (*1, 4, 5*).

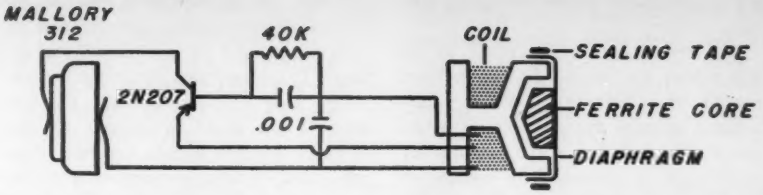

Fig. 1. Frequency-modulated radio telemetering transmitter which can be swallowed or otherwise inserted into body cavities to transmit pressure indications.

An Active Transmitter

The variable which has thus far been of most interest is the pressure whose fluctuations accompany peristaltic activity in the gastrointestinal tract. In our laboratory the unit shown in Fig. 1 is often used for its transmission. A 250-turn center-tapped coil is used in a Hartley circuit, the capacitors having a common point so that small three-wire double ceramic units can be used. A Burgess or Mallory mercury cell (*6*) will power the unit for about 3 days with a resistor of the size shown, placed as shown. With a similar circuit, a small nickel-cadmium cell has been recharged within the body by an external oscillator (*6*). A gastric-juice battery is a possibility, but it seems unreliable (*1*). With typical components, the pill is 9 millimeters in diameter and 25 millimeters long after it is enclosed in a disposable rubber finger cot. A smaller diameter was desired for endoradiosondes which were inserted into the human bladder for studying pressure changes during micturition, and handmade zinc-platinum cells of less stable voltage were employed (*6, 7*). The pills have either been mounted in

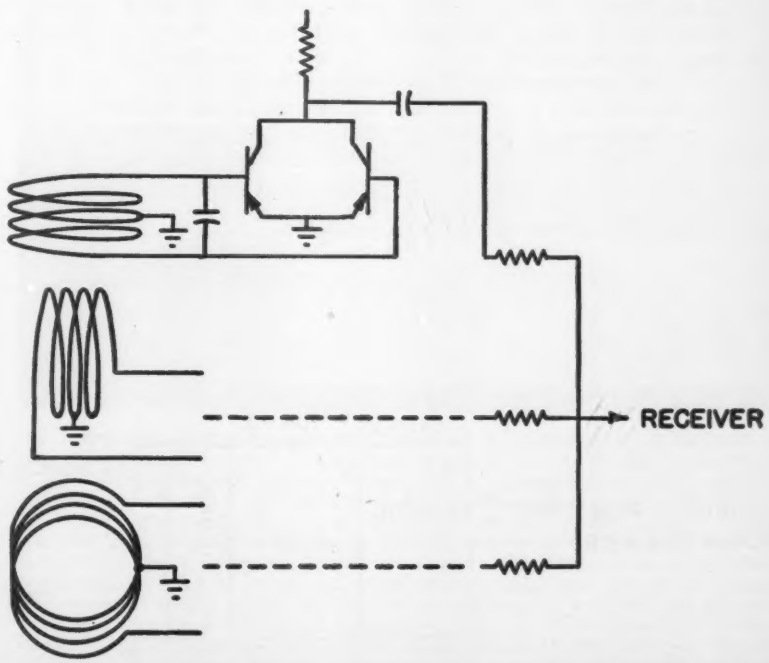

Fig. 2. Three perpendicularly oriented receiver antennas feeding frequency doublers whose outputs are added before presentation to the receiver. The signal is approximately constant for any orientation of the transmitter. Not shown is a stage of amplification that follows the antennas to insure nonlinear action.

a Lucite body or potted in silicone rubber.

The ferrite core (*7*) is glued to the thin rubber diaphragm; air leakage from behind the diaphragm is carefully avoided because this air cushion determines the restoring force. Frequency modulation is produced by motion of the core. Because the diaphragm supplies little of the restoring force, its changes with age and with passage through various body fluids do not cause major drift. There is still some residual drift, possibly due to gas diffusion, that interferes with long-term absolute measurements, but this does not interfere with the observation of peristaltic patterns. Sensitivity can be checked while the unit is within the body by varying the "atmospheric" pressure on the subject (*1, 8*), but this is usually unnecessary. Orientation sensitivity is minimized by the use of a light core, and barometric effects seldom occur rapidly enough to cause difficulty. A conducting rather than a magnetic core (*7*) is convenient in experiments in which one is attempting to restrain the pill or to introduce mechanical motions by external magnets. The pills that were inserted into the bladder were enclosed in a slightly inflated condom, so that pressure changes throughout a volume could be recorded, rather than forces applied at one end (*6*). This also reduces diaphragm leakage. Metallic and plastic diaphragms can also be used.

A change in temperature can shift the output frequency of the transmitter. In studies of human beings this can be convenient because a change in frequency after the subject has taken a sip of cold water is a clear signal that the endoradiosonde is still in the stomach and has not yet advanced into the intestine. Temperature sensitivity can be either enhanced or minimized. An increase in temperature affects the transistor in such a way as to drop the frequency; this effect is opposed by the effect on the gas pocket, on the tuning condenser (if it has a negative temperature coefficient), and on the ferrite core (*6*).

Various modifications (*8*), including use of a different turn ratio to prevent blocking, instead of a base resistor, and a split shield that simplifies calibration, have been demonstrated. A Clapp circuit minimizes the effect of the transistor (and thus the voltage) on frequency (*9, 10*). Capacitive as well as inductive transducers have been tested, and resistive ones consisting of conducting epoxy resin or of a liquid containing a hollow plastic sphere between electrodes gave fair performance. A small booster transmitter, with a frequency shift between input and output to prevent oscillation, can be used to relay the signal and give the subject freedom of movement (*6*).

Antenna Systems

Antenna coils are used in magnetic systems and body electrodes in the other systems. The active transmitter discussed above is often used in connection with a receiving loop, of 6-centimeter diameter, tuned to the operating frequency range of a few hundred kilocycles per second. Directional effects can be eliminated by using three orthogonal (or otherwise oriented) coils and switching between them, or by adding their outputs after frequency doubling and noting the variations in this doubled frequency at the receiver (*6*) (Fig. 2). Another way to achieve this result and yet avoid having rotating coils in the probe is to use a transformer-coupled radiogoniometer.

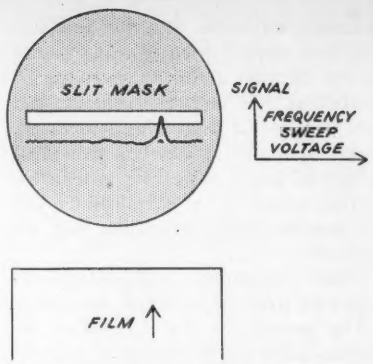

Fig. 4. Simplified arrangement for producing a time graph from a cyclically scanned narrow-band detector output.

Omnidirectional schemes for passive transmitters are generally somewhat more complicated (*11*). For either absorption or emission, the most convenient method seems to be to use commutation and slip rings, or switching transistors, to switch between antennas, in each of which a complete analyzing function can take place. Recording is from the one, or ones, with the largest signal.

Because the wavelength is long as compared with the size and separation of the antennas, these experiments are carried out in the induction or near field. The coils can be considered as dipoles for many purposes. It seems possible, in principle, to have coupling for all orientations with only two perpendicular external coils, if the axis of one does not pass through the center of the other.

There are several receiving systems which can be used to determine these variations in frequency. In general, frequency-measurement systems can be divided into scanning systems and cycle-counter systems. Amusing arguments on the reality of side-band frequencies in modulated waves have arisen, since the former systems show them and the latter do not. Here, a parallel bank of simultaneously acting tuned filters is considered as a scanning system; its output can be scanned rapidly. Various forms of both systems are applicable to the present problem.

It is characteristic of digital systems that they are able to record a high fre-

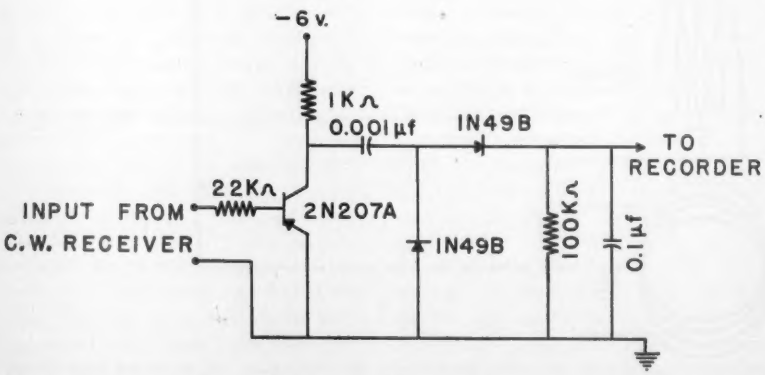

Fig. 3. Frequency-meter circuit which, when fed from the loud-speaker connection of a suitable receiver, will deliver a direct voltage proportional to frequency but relatively independent of amplitude.

quency and a large range of frequencies with an excellent degree of discrimination. Standard counting circuits can work at these frequencies, and crystal-gated ones have been used in such applications. In an alternative approach, use is made of a standard continuous-wave receiver in which the incoming frequency beats with a local frequency to give a lower frequency which varies rapidly with small percentage changes in the incoming radio-frequency signal. The normal loud speaker output can then activate a resonant or gated-charge frequency sensor (*7*). In our laboratories it is customary to use this simple system with a well-stabilized local oscillator, and to feed the beat signal into a clipper circuit and "diode-pump" frequency meter and chart recorder, as shown in Fig. 3. This beat-frequency signal can be recorded directly on a magnetic tape for possible automatic analysis, and later it can be played into the demodulation circuit, if desired.

The permissible radio-frequency deviation is limited to the bandwidth of the receiver if loss of signal is never to

The permissible radio-frequency deviation signals by tracking them with a standard automatic frequency-control circuit, the frequency-discriminator signal then being the useful output (*8*). This is equivalent to continuously retuning the receiver with a servomotor or speaker-driven capacitor.

Another method is to scan a narrow-band filter cyclically through the possible range of frequencies until a response is found (*8*). This is usually done by sweeping the oscillator in a heterodyne system. The method is illustrated in extremely simple form in Fig. 4, which shows the arrangement actually tested in the early transmitters that employed passive transmission and a sweeping grid-dip meter circuit. At the frequency where there is a response, the oscilloscope trace becomes visible as a spot above the mask. This horizontally moving spot is recorded on the steadily moving film as a wavy line which is a graph of pressure as a function of time. Similarly, circuits can indicate where in the sweeping cycle the response occurs and generate a signal proportional to the time after the start of sweeping (*12*). This procedure overcomes noise in a predictable fashion at the expense of response time by processing the signal over successive small intervals (*11*).

Several variables, besides pressure, have simultaneously been transmitted from a single oscillator through multiplexing by blocking. The original circuit (*1*) was essentially the circuit of Fig. 1 without the resistor. It periodically turned its pressure-transmitting oscillations on and off at a rate dependent on temperature. A few cycles of oscillation bias off the transistor; after this there are a few cycles of ringing. Oscillations in successive bursts are not generally phase-coherent if there is no master oscillator, and the phase shifts introduce extraneous side bands. In the simplest method of analysis, tuned circuits are dispensed with and the signal passes through a wide-band amplifier into an oscilloscope for direct observation; the latter can be replaced by broad-band analyzing circuits. If both slow and

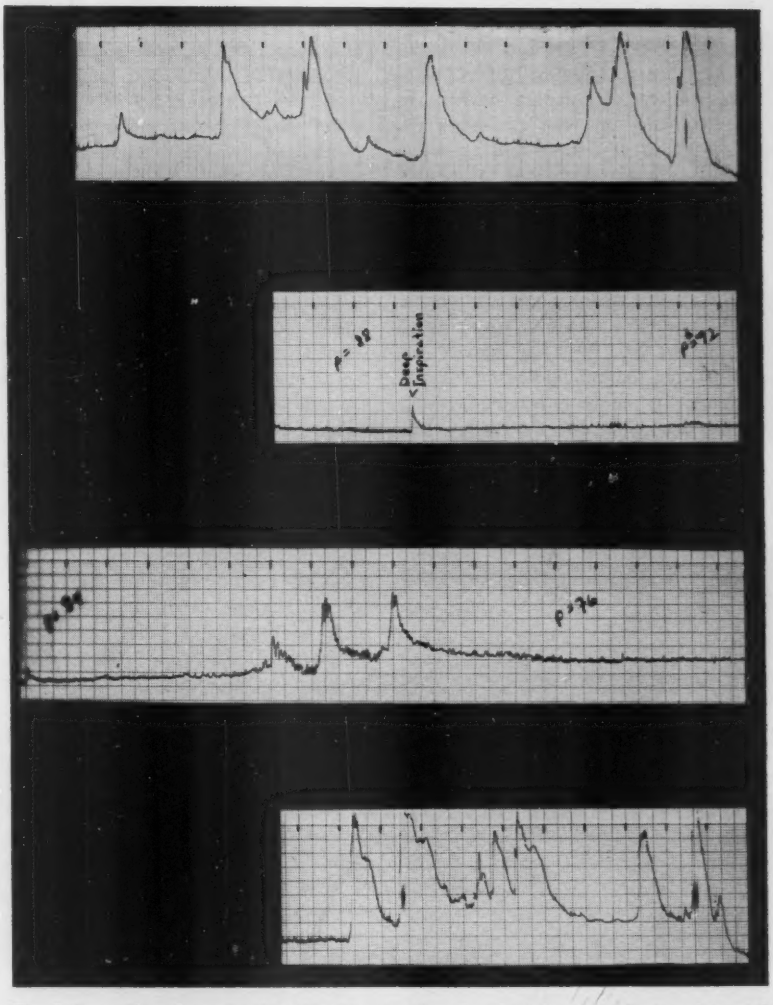

Fig. 5. Recordings from the sigmoid of a normal male. (Top) Seventy minutes of normal peristalsis was observed prior to administration of atropine sulfate. The contractions, of 3 to 7 minutes' duration (pressure increase, 110 to 190 mm-Hg), were interrupted by relaxation periods of 1½ to 4 minutes. (Second from top) Intravenous administration of atropine sulfate (0.4 mg) (pulse rate, 80) was followed by a 9-minute period of muscle relaxation (no change in pulse), then by three contractions of the type described. The subject fell asleep and slept for 22 minutes, during which time there was no recorded bowel activity. When he awoke, the original pattern reoccurred. Administration of a second dose of atropine sulfate (0.6 mg), 80 minutes after the first dose, was followed by 24 minutes of muscle relaxation (pulse, before injection, 80; 16 minutes after injection, 92). (Second from bottom) After the muscle relaxation there occurred a period of contraction of about 4 minutes' duration (increase in pressure, 90 mm-Hg), followed by 15 minutes of bowel relaxation (pulse, 76). (Bottom) A second period of contraction, recorded 42 minutes after the 0.6-mg dose of atropine sulfate, lasted 7 minutes, but pressure increased by only 26 mm-Hg. After a 20-minute period of inactivity, contraction frequency and intensity were as originally noted.

periodic rapid variables are of interest, then three simultaneous signals can similarly be sent and received from one oscillator by varying the average frequency (base line), the deviation frequency, and the frequency of an amplitude modulation.

Other Variables

Some variables other than pressure that have been transmitted by various workers are temperature, oxygen tension, acidity, and radiation intensity. In principle, any of these can be transmitted by either a passive or an active system in conjunction with a suitable transducer. Gastrointestinal motility (essentially the progression-producing activity of the gut) is of interest to clinicians and is not identical to pressure variation. More can be told of this by the simultaneous use of a number of transmitters (*6*), by x-ray movies accompanying the endoradiosonde observation, or by the use of a radio tracking device that plots out the two-dimensional component of the motion of the capsule during its passage (*13*).

A transmitter of the type used to transmit pressure in the gastrointestinal tract has also been used to transmit bladder pressure and steadiness in standing (*6*), uterine contractions and fetal heart sounds (*14*), and teeth clenching. When the transmitter is used in variable-acceleration situations, a projecting ring prevents direct pressure by the body on the diaphragm. A piezoelectric sensor is of no advantage here but, if vibrating, can measure viscosity by variable damping.

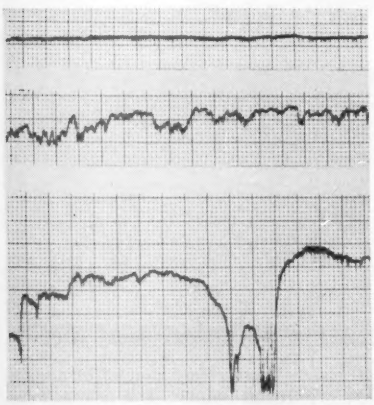

Fig. 6. Spontaneous restoration of peristalsis in the large intestine (cecum) after cessation following the trauma of gallbladder removal. The small regular fluctuations are pressure changes due to breathing. Major time divisions are 20-second intervals. (Top) No activity after 1 hour. (Middle) Ten minutes later, activity starts. (Bottom) Three hours after the previous record. In the top and middle records the deflection times 1.6 gives the pressure in millimeters of mercury; in the bottom record the factor is 3.2.

The sensitivity of the capsule to temperature has been mentioned. Inclusion of a temperature-sensitive reactance can maximize this. A passive transmitter consisting of a coil and temperature-sensitive capacitor (*7*) has recently been tested as a permanently implanted monitor of ovarian function (*15*). The original blocking oscillator (*1*) was quite sensitive in monitoring temperature, and this is essentially the circuit used to study the incubation of penguin eggs in the Antarctic (*16*).

The significance of acidity measurements along the gastrointestinal tract is not always clear, but there are experiments one might wish to perform. For example, one might determine whether administration of vitamin D to a child with rickets changes the *p*H in the intestine as a result of the effect on calcium, or one might investigate whether the difference in intoxicating effect of different alcoholic beverages is due to a buffering action by some and not by others. The use of an antimony electrode to measure *p*H has been mentioned (*6, 17*). These electrodes, though having a low impedance convenient for transistor circuits, are sensitive to various other chemical systems in the body. Thus, the data they transmit, which may prove clinically useful, possibly should be termed "antimony numbers" rather than *p*H. A tungsten electrode seems no better. If the second electrode is made of silver chloride, rather than of standard materials in a wick configuration, then additional sensitivity to chloride ion is found. The original *p*H endoradiosonde (*4*), based on the reversible mechanical expansion and contraction of certain copolymers that accompany changes in acidity, suffers from some of these same difficulties.

The acceptable method of measuring *p*H is to use a glass electrode with a transistor circuit having over 100 megohms of input resistance. Feedback circuits with silicon transistors have been built with this degree of input resistance, and with recent techniques they probably could be sufficiently miniaturized. A better approach seems to be to apply the voltage to a nonlinear condenser whose change in capacity produces frequency modulation in the oscillator. Improvements over the biased-diode variable condensers mentioned earlier (*7*) have been achieved through the use of newer dielectric-amplifier components, and suitable resistance is found both in polarized titanates and in back-biased silicon diodes (*10, 11*). The field-effect transistor appears promising for situations where added gain is needed.

Various bioelectric potentials can be transmitted similarly; a lower input impedance is adequate, and so the direct effect of an injected voltage on the oscillator often suffices. With the high input resistance modulator, one can use the large pyroelectric signals from barium titanate to detect changes in temperature, such as those that may occur at the edge of some inflammations.

A problem that has received some investigation is that of localizing the site of internal bleeding along the gastrointestinal tract, or even of distinguishing stomach bleeding from duodenal bleeding. In an appreciable number of clinical cases this site is difficult to determine by present methods. Several approaches have been tried that would sensitize an endoradiosonde to the presence of blood. Chemical methods seem ambiguous when applied to the normal contents of the tract, but possibly some colorimetric method could be made to work. Oxygen tension can be measured by the reversible mechanical expansion and contraction of certain chelates (*18*), which can be encased in a thin film of Teflon for protection (*1, 6*). These can be used with a pressure endoradiosonde to detect the presence of a pool of blood, though swallowed air can interfere with such an observation. Powering the oscillator with an oxygen depolarized battery (reduced version of Eveready 1002 E), or with a fuel cell with hydrogen reservoir, gives similar results. A polarimetric method has been reported for this same purpose (*19*). Promising approaches search for the presence of the red corpuscles themselves. Erythrocites, because of their thin capsule, have insulating properties and a very high effective dielectric constant. However, direct electrical measurement is complicated by the active sloughing off of cells by the lining of the gut (*11*).

Red corpuscles can be labeled with any of several beta-active radioactive

elements (*20, 21*) and then reinjected into the donor. Relatively simple animal experiments employing a Geiger counter with a little shielding show that one can detect a lesion if some of the red corpuscles have been labeled (*21*) with phosphorus-32. Decomposition products in the bile do not seriously interfere. Such a label lasts only about 2 hours, and thus several endoradiosondes, simultaneously operating on different frequencies, would have to be placed at intervals along the gastrointestinal tract. A preliminary discussion of low-voltage radiation detectors for this purpose has been given elsewhere (*7*).

A transistor with a floating base connection is quite sensitive to light. Thus, if the cover of the transistor in Fig. 1 is removed, small changes in light intensity will produce frequency modulation of the output signal. An even more sensitive circuit is obtained by replacing the resistor in Fig. 1 with a cadmium sulfide cell; in this circuit the radio-frequency oscillations are periodically interrupted at a frequency that depends on the light intensity. In this last application a silicon transistor (for example, the Pacific Semiconductor, type PMT-012) gives a better blocking action at the elevated temperatures of the body. With a radioactive or other light source, these circuits could perhaps be used for colorimetric measurement. In conjunction with a scintillation plastic or crystal, they also make a low-voltage radiation-sensitive unit that has applications in radiology. Because of the inefficient use of the light, such a radiation detector is at present too insensitive, by several orders of magnitude, to detect the presence of beta-particle-emitting red corpuscles. The junction region of a transistor shows direct sensitivity to beta particles, but because of thinness, little of the particles' energy is made available, and insensitivity results. The sensitivity of a Geiger counter is needed, and tiny ones are readily fabricated. A small several-hundred-volt blocking-oscillator power supply was constructed in which an elevated counting rate, due to increased loading, caused a shift in frequency (to combine transmission and modulation with voltage generation). Radiation of the signal must be from a separate coil of a few turns around the capsule when a ferrite core transformer is used to step up the voltage. Small mechanical motions can be introduced into these capsules by the subject himself, by external pressure changes, or by the use of external magnets, and thus one might alternatively consider using either an electrophorus or an electret as an electrostatic voltage source for these small currents. Radioactive batteries and small voltaic piles are other possibilities. A resistance-strip magnetic multiplier (*22*) could probably be miniaturized, but it would present the same voltage-source problems.

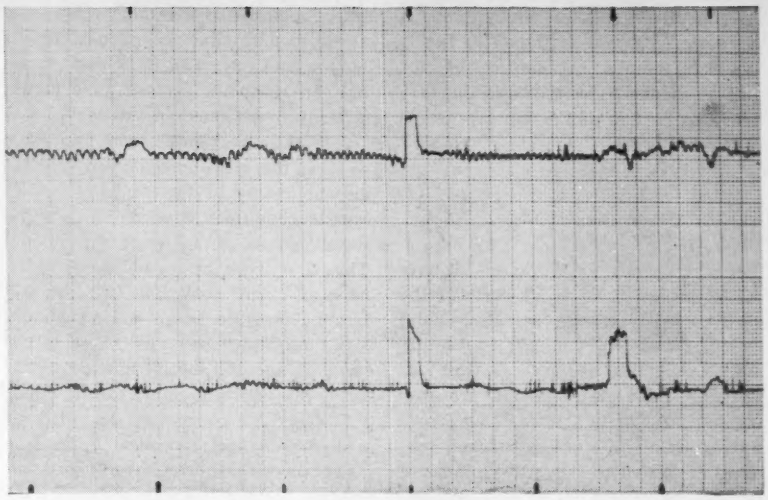

Fig. 7. Simultaneous signals from two transmitters, the upper from the esophagus and the lower from the stomach, of a representative healthy subject as various maneuvers were performed (marks at top, from left: swallow, swallow, Valsalva, Müller, deep inspiration). Increase in pressure is upward, with sensitivity in the top channel approximately half that in the lower channel. The small regular fluctuations are due to breathing. Marks at bottom, 1-minute intervals.

Alpha particles, because of their high density of ionization, are able to directly activate a transistor more vigorously (again through use of a floating base connection). The best solution thus may be to label the corpuscles with an alpha emitter. One beta-labeling procedure (*20*) also produces alpha-active daughter products that tend to remain in the corpuscles, and some such method may prove satisfactory. Only those corpuscles directly in contact with the detector would be detected. Taking the relative biological effectiveness of alpha particles as being between three and ten times that of beta particles, one can calculate the permissible dose for a human being, and the result indicates the practicality

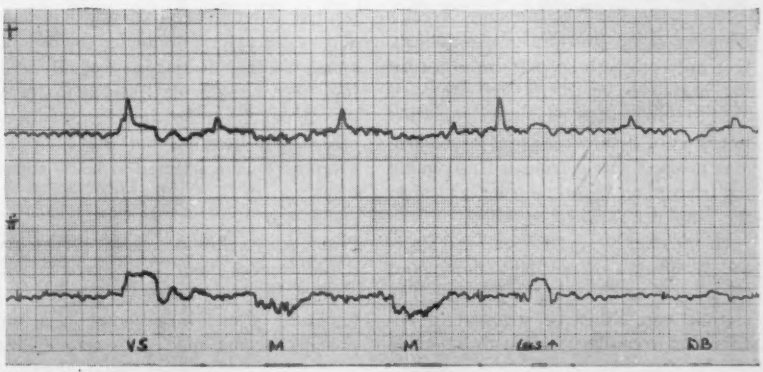

Fig. 8. Recordings from a subject with hiatus hernia; the upper tracing is from the esophagus, the lower from the pouch above the diaphragm. Normal periodic contractions are seen in the top tracing. The deflection in millimeters (small divisions) divided by 1.5 for the top tracing and 0.4 for the bottom tracing gives the pressure in millimeters of mercury. *VS*, expiration against resistance; *M*, inspiration against resistance; *DB*, deep breath (sometimes producing a drop in both channels); *Legs*, raising legs from bed.

of obtaining a distinct pulse every few seconds in the circuit, with practically no confusing radiation background. A bit more gain than is shown in Fig. 1 would be required between the detector and the oscillator; nevertheless, this may prove to be one of the more practical methods.

Clinical Observations

Various groups of workers (*23*) have made recordings from all parts of the gastrointestinal tract, as have John Carbone and I. I will cite a few examples of clinical observations from our studies in connection with the pressure-transmitting unit. These units have proved useful in studying normal patterns of activity. They are important because the subject has no sensation and thus is in a relatively normal, nonapprehensive state. The observations can be more reliable than the sometimes exaggerated readings obtained with the inflated-bag technique, in which both the size of the bag and its trailing attachment are disadvantages. Since the signal does not travel along a pneumatic tube, the frequency response is good. The spot in the body occupied by the endoradiosonde can be determined approximately by using the receiving antenna in a direction-finder fashion, and more accurately by radiography. Passage from the stomach is often judged by the temperature response to a sip of cold water.

The pressure-sensitive capsule can transmit the small pressure fluctuations due to breathing, and even smaller ones due to arterial pulsations are often observed; on the other hand, the same type of transmitter in the sigmoid has recorded momentary pressures greater than the blood pressure of the subject. Not only are normal patterns recorded but it is possible to test the effects of various drugs—for example, spasmolytics. Figure 5 shows a series of recordings in the sigmoid from a freely moving transmitter before, during, and after the administration of atropine.

In the field of surgery, one can study the restoration of normal activity after the trauma of a surgical procedure. The capsule can either be ingested in advance or it can be inserted through the wound, where it will stay until the return of normal activity forces it onward. Figure 6 is a tracing from such a study. The effect of such drugs as Hopan or Cozyme in hastening intestinal activity in the postoperative period is being investigated in this way.

To take an example from the other end of the gastrointestinal tract, and an application in the study of pathological conditions, we might note the simultaneous use of two transmitters. The same type of transmitter is used here as in the experiments described, but the pressure range is considerably less. One transmitter was placed in the stomach and the second in the esophagus of a normal subject, and their simultaneous signals were recorded on a double-channel recorder, as in Fig. 7. The two transmitters were kept from moving onward, without discomfort to the subject, by threads extending up into his mouth and tied around a tooth. The results of various maneuvers may be seen. Similar observations on subjects with hiatus hernia are being compared with the results of these various maneuvers in normal subjects. In hiatus hernia the stomach does not lie entirely below the diaphragm, which is normally penetrated by the esophagus, and a fold of the stomach itself extends up through the diaphragm. Figure 8 is a record made with one transmitter in the esophagus and the other in the pouch above the diaphragm. We hope that by recording the relative pressures in the areas above and below the diaphragm and in the esophagus we can learn why some patients suffer distress from this condition while others never know they have it. Possibly there is a physical explanation involving the shifting back and forth of the stomach contents with normal activity. The pressure difference across the pyloric sphincter has significance in other diseases as well. Recordings have been made from all parts of the alimentary tract and from various other body cavities, but the examples given here were selected as being somewhat varied. (For other relevant references, see *24*.)

As new techniques develop, the endoradiosondes can be made much smaller. For the alimentary tract, the presently available commercial components seem quite satisfactory, but extreme miniaturization and passive transmission are needed, for example, for placing a pressure transmitter in the anterior chamber of the eye of an experimental animal in order to study glaucoma (*25*).

References and Notes

1. R. S. Mackay and B. Jacobson, *Nature* **179**, 1239 (1957).
2. J. T. Farrar, C. Berkley, V. K. Zworykin, *Science* **131**, 1814 (1960).
3. M. Marchal and M. T. Marchal, French patent No. 1,200,043.
4. B. Jacobson and R. S. Mackay, *Lancet* **1957**, 1224 (1957).
5. J. T. Farrar, V. K. Zworykin, J. Baum, *Science* **126**, 975 (1957); M. von Ardenne and H. B. Sprung, *Naturwissenschaften* **45**, 154 (1958).
6. R. S. Mackay, *IRE Trans. on Med. Electronics* **ME-7**, 67 (1960).
7. ———, *ibid.* **ME-6**, 100 (1959).
8. ——— and B. Jacobson, *Electronics* **31**, 51 (1958).
9. P. G. Sulzer, in *Transistor Circuits and Applications*, J. M. Carroll, Ed. (McGraw-Hill, New York, 1957), p. 18.
10. H. S. Wolff and R. F. Russ, *Proc. Intern. Conf. Med. Electronics, 3rd Conf., London, 1960* (Institution of Electrical Engineers, London, 1961).
11. R. S. Mackay, *ibid.*, p. 115.
12. B. Jacobson and B. Lindberg, *IRE Trans. on Med. Electronics* **ME-7**, 334 (1960).
13. B. Jacobson, Proc. Intern. Conf. Med. Electronics, 4th Conf., New York, 1961, in press.
14. C. N. Smyth and H. S. Wolff, *Lancet* **1960**, 412 (1960).
15. H. S. Dordick, H. Balin, S. L. Israel, F. Hatke, Proc. Intern. Conf. Med. Electronics, 4th Conf. New York, 1961, in press.
16. C. R. Eklund and F. E. Charlton, *Am. Scientist* **47**, 80 (1959).
17. M. von Ardenne, *Proc. Intern. Conf. Med. Electronics, 2nd Conf., Paris, 1959* (Iliffe, London, 1960), p. 268; H. G. Noller, *ibid.*, p. 296.
18. A. E. Martell and M. Calvin, *Chemistry of the Metal Chelate Compounds* (Prentice-Hall, New York, 1952), chap. 8.
19. H. G. Noller, Proc. Intern. Conf. Med. Electronics, 4th Conf., New York, 1961, in press.
20. G. Hevesy, *Arkiv Kemi* **3**, 425 (1951).
21. P. L. Mollison and M. A. Robinson, *Lancet* **1958**, 766 (1958).
22. L. Heroux and H. E. Hinteregger, *Rev. Sci. Instr.* **31**, 280 (1960).
23. J. T. Farrar and J. S. Bernstein, *Gastroenterology* **35**, 603 (1958); H. P. Sprung, *Proc. Intern. Conf. Med. Electronics, 2nd Conf., Paris, 1959* (Iliffe, London, 1960), p. 281; A. M. Connell and E. N. Rowlands, *Proc. Intern. Conf. Med. Electronics, 3rd Conf., London, 1960* (Institution of Electrical Engineers, London, 1961).
24. M. A. Wenger, E. B. Henderson, J. S. Dinning, *Science* **125**, 990 (1957); H. B. Sprung, *Arch. klin. Chir. Langenbecks* **291**, 80 (1959); J. McCall, *Proc. Intern. Conf. Med. Electronics, 3rd Conf., London, 1960* (Institution of Electrical Engineers, London, 1961); L. C. Payne, *Science* **131**, 611 (1960); B. Jacobson, *IRE Trans. on Bio-Medical Electronics* **BME-8**, 192 (1961); S. J. M. England and B. Pasamanick, *Science* **133**, 106 (1961); J. Nagumo, A. Uchiyama, S. Kimoto, T. Watanuki, K. Suma, A. Ouchi, M. Kumano, H. Watanabe, data for the Special Committee on the Study of Electronic Apparatus for Medical Application, Japanese Society of Communication Engineers (1961).

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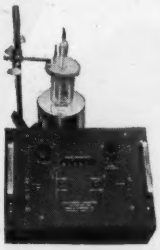

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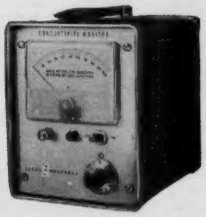

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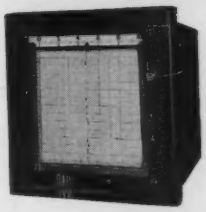

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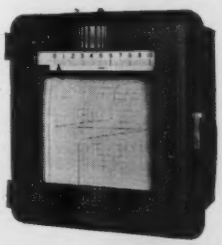

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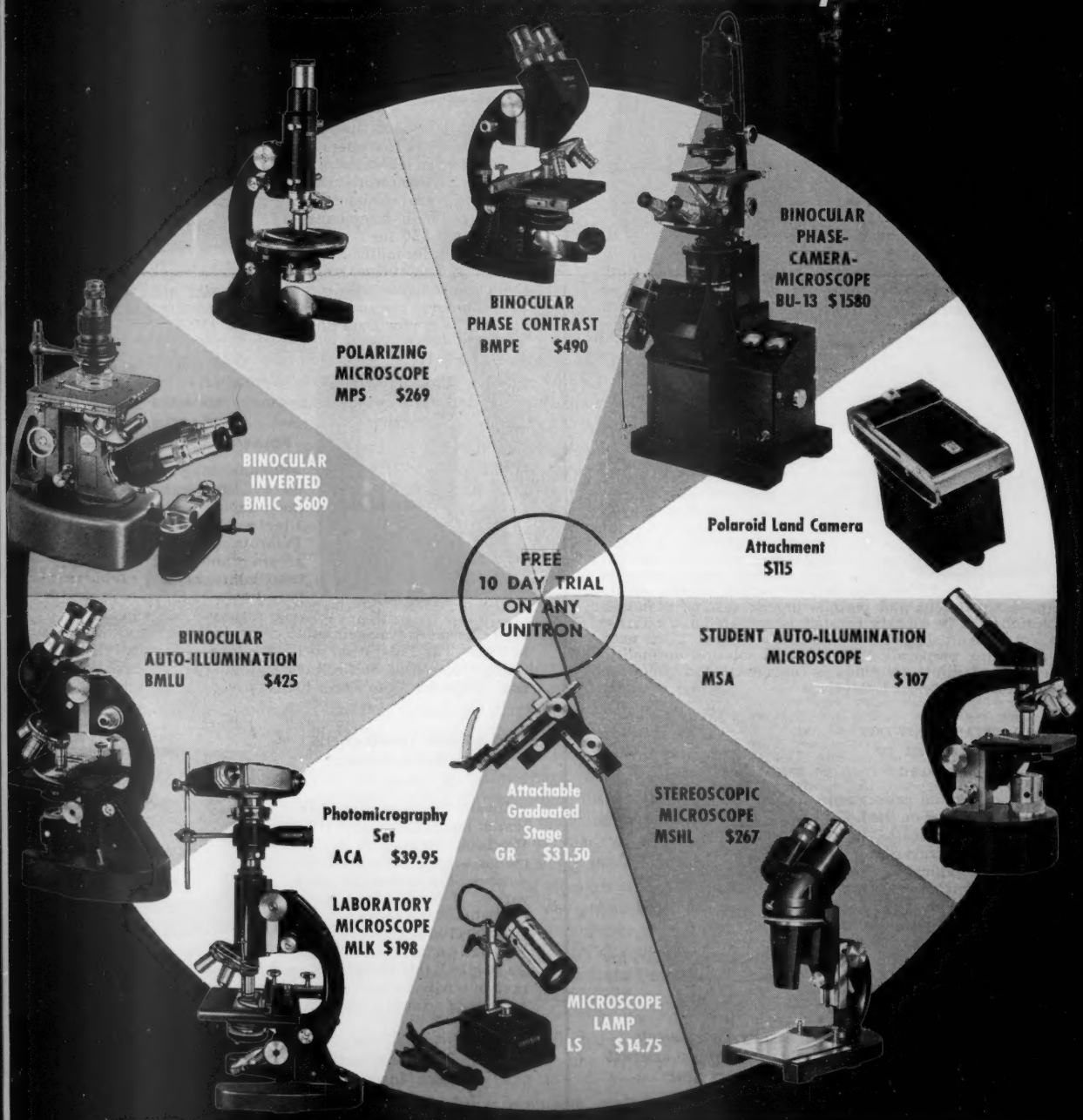

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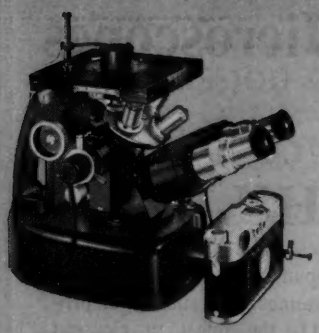

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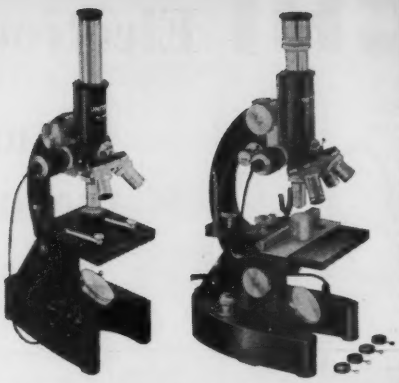

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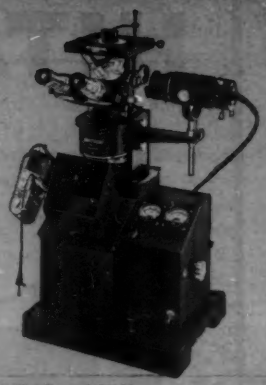

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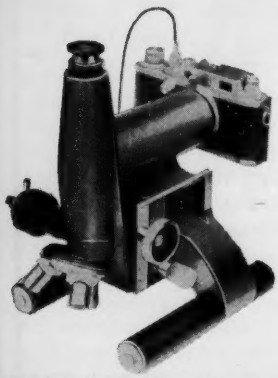

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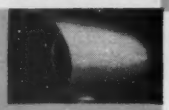

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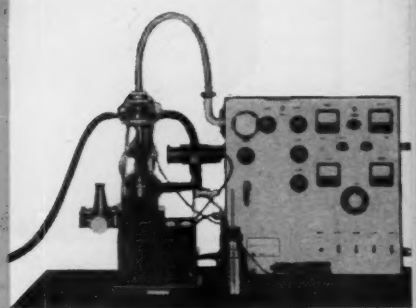

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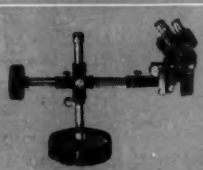

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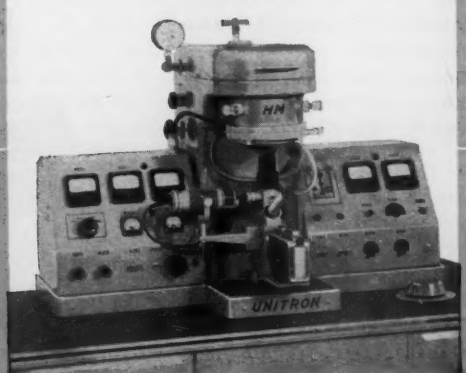

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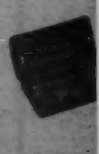

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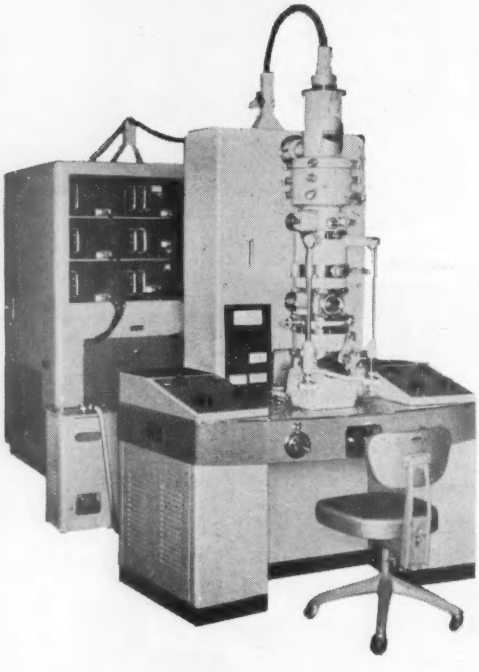

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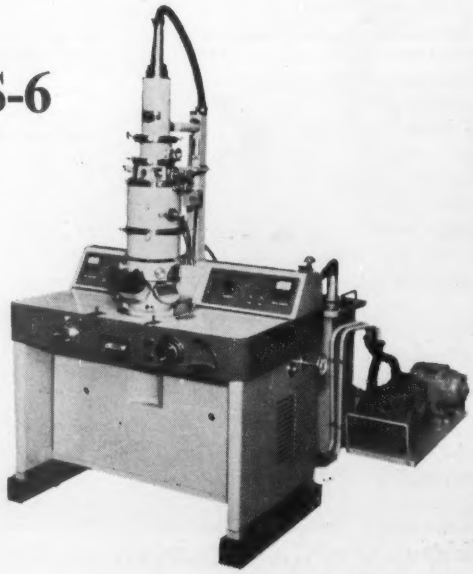

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Emission Spectrochemistry in Nutrition Research

The potential utility of spectrochemistry in mineral nutrition research is not yet fully exploited.

C. L. Grant

"As well as can be judged from the literature, biological spectroscopy has not been troubled by too much imagination. In fact, one can briefly describe the cookbook recipe of experimental design: take a certain amount of urine, blood, or tissue of some animal or man. Destroy the organic parts with perchloric acid, fire, or sword until they have returned to ashes. Introduce the ash into a flame, an arc, or a spark, and photograph the spectrum. If unexpected metals are found, the literature has been enriched by two papers: the first one reporting the presence of an unusual metal, perhaps a rare earth; the second paper, a letter to the editor, contending that this new and startling finding represented contamination" (*1*).

Unfortunately the foregoing quotation seems to apply to a large amount of the mineral-nutrition research done in the past. This situation arose partly because much of the work was done by spectrochemists, whose primary purpose was to demonstrate the feasibility of applying spectrochemistry in this area of research. That this goal was achieved is evidenced by the large number of nutritionists presently interested in the technique as a means of obtaining useful data on mineral nutrients in various systems. The existing shortage of personnel thoroughly trained in spectrochemistry makes virtually inevitable a rapid increase in the number of people who will become "part-time spectrochemists" while remaining primarily interested in the elucidation of the fundamentals of mineral nutrition. It is important, therefore, that these people be thoroughly familiar with the basic concepts of spectrochemistry.

Emission spectrochemistry embraces all analytical methods based on the phenomenon that energized atoms, ions, and molecules emit electromagnetic radiation when they lose energy. In this article (*2*), attention is focused on optical emission spectrochemistry, the greatest emphasis being placed on the vaporization and excitation steps. In addition, I shall seek to clarify some misconceptions about the capabilities that this technique possesses, or that it may be expected to possess with further improvements in methodology. Some specific examples of the use of the technique in nutrition research are included.

Basic Principles

In 1944, Churchill (*3*) voiced the opinion that, "because of the almost unlimited number of combinations and permutations of electrical, optical, chemical, and physical variables possible in a spectrochemical analysis, and because of the interdependence of these variables on each other, there is no optimum value for any one of the variables except in relation to all of the others." Let us, then, first examine the over-all problem.

In qualitative analysis, the spectral lines emitted by an excited sample are generally photographed on a film or plate. When only a few specific elements are sought, their lines are usually identified by comparison with spectra of the pure elements, photographed in juxtaposition. In other instances it is often necessary to determine the wavelengths of lines by measuring precisely the distances that separate them from lines of known wavelength.

Quantitative analysis, on the other hand, is based on the fact that the intensity of a spectral line of an element is a function of the amount of that element in the source. To obtain a relative measure of intensity, photographic densities can be measured with a densitometer or microphotometer, these values being converted to relative intensities by means of an emulsion calibration curve relating these two variables. Strock (*4*) indicated some of the difficulties in this procedure and emphasized that photographic intensities are only relative measures of light-source intensities. Recently, direct-reading instruments, in which light intensities are recorded photoelectrically, have become very popular. Although these instruments are more expensive and less versatile than photographic ones, they eliminate many errors inherent in photographic procedures, thereby providing excellent precision for routine high-speed analyses. Apparently, then, quantitative analysis should involve only the construction of an analytical calibration curve relating the intensity of a line to the known amount of the element responsible for that line in a series of standards. This approach was employed with some success by Slavin (*5*) in his "total energy" method, but it has not gained general acceptance because of the multitude of factors that affect the total amount of light emitted by a given weight of an element. The interested reader can find numerous references to these factors in any one of several books—for example, Harvey (*6*).

Many of the difficulties of the "total energy" method can be overcome by using the principle of internal standardization, first introduced by Gerlach (*7*) in 1925. In this procedure, concentration of the element to be determined is measured in terms of the ratio of the intensity of the analysis line to the intensity of a "homologous" line of another element present in fixed concentration in all samples and standards. Uncontrollable fluctuations that affect the intensities of both lines to the same extent should not affect the intensity ratio between them. Unfortunately, complete success has never been attained in efforts to find line pairs whose intensity ratios are insensitive to changes in chemical and physical composition. Despite some limitations, the internal-standard principle placed quantitative analysis by optical emission spectrochemistry on a firm foundation.

There are four main steps involved in the technique: (i) vaporization and

The author, former associate professor of soils at the New Jersey Agricultural Experiment Station, Rutgers University, New Brunswick, is presently affiliated with the Engineering Experiment Station, University of New Hampshire, Durham.

excitation, (ii) resolution of emitted radiation into its constituent wavelengths, (iii) recording of spectral lines, and (iv) interpretation. Each of these steps is considered separately below.

Vaporization and Excitation

Vaporization is generally accomplished by thermal means, as with flames and arcs, or by bombardment with positive ions and high-velocity electrons, as exemplified by the high-voltage spark source. But this process is never entirely thermal or entirely one of bombardment, and there is no sharp separation between arc and spark sources. Considerable effort has been expended in the development of "hybrid" sources that combine the more desirable features of both arc and spark (*8*, *9*). Only three basic excitation sources will be considered here: flames, arcs, and high-voltage sparks.

Optical emission spectrochemistry is a technique for analyzing light emitted by atoms, by ions, and by some molecules that have been sufficiently excited to cause valence electrons to move to higher energy levels than they occupy in the stable state. The radiation emitted when an electron returns to a lower energy level appears as light of one or more discrete wavelengths that are characteristic of the atom of the element producing them. Each element is characterized by as many different spectra as the atom has electrons. Thus, the lines originating from electron transitions in the neutral atom are often called arc lines, whereas those from the singly ionized atom are called the first-spark spectra. Greater degrees of ionization do occur to a limited extent in conventional spectroscopic sources, but the lines originating from these ions are only occasionally of analytical importance.

Excitation of atoms in a discharge can be accomplished by (i) transfer of energy through collisions with atoms and ions that are already excited (collisions of the second kind); (ii) inelastic collisions with high-velocity electrons; and (iii) absorption of radiation (*10*). In addition, atomic spectra may be produced when the bonds in a molecule are ruptured (*11*). The process involves a change in an electron from a molecular orbit to an excited atomic orbit and, finally, a return to the ground state which produces the characteristic spectral line or lines. The relative activity of each of these processes depends on a multitude of factors and varies greatly in different types of sources.

All the elements can be excited, but gases and bromine and iodine are only infrequently determined in this way because they must be excited in sealed systems. These elements can sometimes be determined with conventional apparatus by measuring the band spectra of a compound such as calcium fluoride, but this approach has never been generally used. Carbon, phosphorus, and sulfur, whose sensitive lines lie below 2000 A, have been studied intensively only since the advent of vacuum spectrographs, during the last few years. Most elements that are readily studied by optical emission spectrochemistry produce useful lines (including their most sensitive ones) between 2000 and 10,000 A.

The energy required to excite the arc lines of most elements commonly studied by this technique ranges between 1 and 10 electron volts. To excite spark lines, the energy must be greater than the ionization potentials of the neutral atoms, which range from 3.89 electron volts for cesium to 24.48 electron volts for helium. Meggers (*12*) pointed out, however, that none of the elements commonly determined have ionization potentials greater than about 10 electron volts. Because of this relatively low energy requirement, several different sources of excitation have been used successfully; the most popular are flames, arcs, and sparks.

In flame sources the vaporization step is largely thermal. The minute droplets of solution dry to solid particles that vaporize and dissociate as gaseous atoms or molecules. These are excited by inelastic collisions with high-velocity molecules liberated by chemical reaction between the fuel gases. Commonly used gas mixtures yield temperatures ranging between 2000 and 4800°K, high enough to vaporize most materials. The relative proportions of the various excited species created depend to a great extent on the temperature of the flame. In general, low-temperature flames only excite lines whose excitation potential is low; for example, the oxyacetylene flame is not useful for exciting lines of excitation potential greater than about 5.5 electron volts. It is not difficult to understand why low-temperature flames are not very useful for exciting elements whose strongest lines have large excitation potentials. Until recently, therefore, the flame source was used mainly for the determination of alkalies and, to a more limited extent, of alkaline earths. The advantages of the flame are primarily the simplicity of the spectra and the stability of emission, which makes for high precision.

Recently there has been a pronounced renewal of interest in the flame source as a means of exciting refractory elements. One reason for this is the development of sources of much higher temperature, such as the oxycyanogen flame described by Baker and Vallee (*13*) and by Vallee and Bartholomay (*14*). This source is capable of providing satisfactory excitation of such elements as beryllium and molybdenum. Robinson (*11*) postulated that enhancement in such sources is not due entirely to temperature increase but is due in part to the ultraviolet light that is radiated by the reacting gases and absorbed by the elements, thereby causing excitation.

Perhaps of much greater importance was the discovery that organic solvents increase the emission intensity of many elements by a factor of 10 or more in such conventional flames as oxyacetylene. Gilbert (*15*) reported that line intensities of several elements were enhanced by a factor of approximately 1000 when alcohol was used in an air-hydrogen flame [a good review is given by Dean (*16*)]. The mode of enhancement by organic solvents is not completely understood. Reduction in surface tension gives rise in the mist to droplets of a smaller mean diameter and a greater emission intensity. Reduction in viscosity also tends to produce enhancement. To some extent, increase in temperature in the presence of organic solvents may be a factor, although Gibson and Cooke (*17*) indicated that organic solvents can actually lower the flame temperature. Robinson (*11*) suggested that efficiency in producing free atoms to be excited may increase in the presence of organic solvents, because the dissociation process is exothermic, rather than endothermic as in the case of aqueous systems.

Despite the pronounced increase in sensitivity that resulted from these studies, the flame source still cannot be considered ready for application to nutrition studies involving trace elements other than the alkalies, whereas optical emission spectrochemistry is most useful in the field of trace analysis. Nevertheless, flame sources have been and will continue to be used to good advantage in the determination of alkalies and alkaline earths in a great variety of materials involved in nutrition re-

search. It is not unreasonable to expect that, with increasing knowledge of the fundamentals of excitation in these sources, they may eventually become useful for trace determinations of many metals.

Traditionally, the direct-current arc has been the source chosen for most trace-element analyses of such nonconducting samples as the inorganic ashes of biological materials. It was the simplest and most versatile source available and provided maximum sensitivity in most cases, primarily because of the large quantity of sample consumed. This source was frequently criticized for its supposed inability to provide the precision required for quantitative work. But relative precision values in the range of ±5 to 15 percent are quite adequate for procedures used in the study of trace elements in biological systems. Methods in which the direct-current arc is employed are capable of this degree of precision when sufficient attention is given to such important aspects as packing of samples in electrodes and selection of analytical and internal standard lines. This is not to imply that we are satisfied with what we have, but only that we should not try to excuse very poor precision on the grounds that this is the best that can be done with this source of excitation. Failure to obtain adequate precision can generally be traced to faulty technique or methodology. But an operator often requires appreciably more training and experience to get precise results with a direct-current arc than with flame or spark sources, and this can be a serious limitation.

For direct-current arc excitation, the sample is generally placed in a crater in one of a pair of conducting electrodes (Fig. 1, *A* and *B*), with a low-voltage arc bridging the analytical gap between the electrodes. Graphite or carbon is the common electrode material, although such metals as copper and silver are used in a few instances. Temperatures produced in the gaseous arc column range between 4000° and 8000°K, depending on the conductivity, which in turn is a function of sample and electrode composition. The intensity of a spectral line depends on the number of atoms that occupy a given energy level and the efficiency with which they are excited. Since both these factors are greatly influenced by temperature, it is not surprising that much effort has been devoted to the measurement of arc temperature as a function of sample-matrix composition. Unfortunately the temperature in an arc column is not homogeneous, not even approximately so. Consequently, theoretical explanations for experimentally observed phenomena developed slowly, but the many papers that have been published on arc-temperature measurements provide a partial understanding of excitation phenomena. The works of Addink (*18*), Duffendack and LaRue (*19*), Leuchs (*20*) are typical of these.

Arc temperature is not the only important variable in direct-current discharges, nor is it the only one not completely understood. Mitteldorf (*21*) pointed out that basic information on functional relationships between such factors as arc current and sensitivity is relatively limited. He also suggested that further study be made of the results of making the sample-bearing electrode, in turn, the anode and the cathode. In most procedures the sample-bearing electrode is made the anode because the anode is much hotter than the cathode and a large amount of sample is thus rapidly volatilized. On this basis one might expect greater sensitivity with anode than with cathode excitation. The difficulty here is that the extremely hot anode radiates a large amount of continuous light that produces a heavy background, and sensitivity is determined by line-to-background ratio rather than by absolute line intensity. Furthermore, Mannkopff and Peters (*22*) showed that most elements emit most strongly in the immediate vicinity of the cathode. Strock (*23*) termed this phenomenon the "cathode layer effect." He found that sensitivity increased by a factor of as much as 100 for some elements in certain matrices if only the light from a 1- or 2-millimeter area directly adjacent to the cathode tip was admitted to the spectrograph. Enhancement was most pronounced for elements of low ionization potential present in trace amounts in small samples (of the order of 1 to 5 mg). According to Mitchell (*24*), who made extensive use of this technique in agricultural analyses, the presence of large amounts of the elements to be determined results in increased emission from the arc column, and the difference between it and the cathode layer decreases.

Mitteldorf (*21*) questioned the necessity of restricting sample size in view of the success achieved in the analysis of high-purity graphite and carbon electrodes by this method, because in such analyses the sample size is relatively unlimited. It might be rewarding to study the "cathode layer effect" for volatile trace elements in large samples (20 to 50 mg) where the volatilization of the matrix could be suppressed by some means. By preventing flooding of the discharge with the major components of the sample, the total number of atoms and ions in the discharge would remain small, since only the volatile elements would be present, and the "cathode layer effect" should therefore manifest itself. One possible method of achieving this result with certain

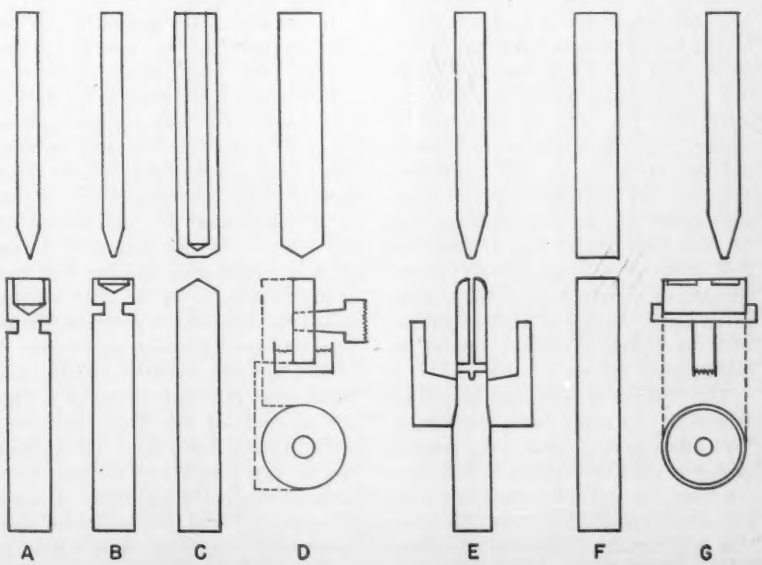


Fig. 1. Cross-sectional diagrams of a few common electrode combinations.

matrices might be to use argon or some other inert atmosphere around the discharge. Vallee and his associates (*25*) and Rupp, Klecak, and Morrison (*26*) reported large gains in sensitivity for volatile elements when inert atmospheres were used. Of the several factors operating in combination, prolongation of volatilization of volatile elements and suppression of matrix volatilization are probably the most important. Since light from the cathode tip was not isolated, the reduction in background as a result of the cooler anode very probably helped. Still another advantage of a gas such as argon is the elimination of troublesome cyanogen-band and metallic-oxide spectra. As a result of such elimination, several very sensitive lines that are normally useless because of the interfering band spectra become available for purposes of analysis.

As for atmospheres around the arc, Stallwood (*27*) demonstrated a marked increase in precision that resulted from blowing a curtain of air upward around the sample as it burned. Substantial reduction of matrix effects was also obtained. Many investigators now combine use of the jet and of inert gases quite advantageously.

A wide variety of electrode shapes have been devised to provide certain desirable properties for various types of sample matrices. Many of these are discussed by Mitteldorf (*28*). Recently much controversy has arisen over the choice between carbon and graphite electrodes. Graphite has been used predominantly in the United States whereas carbon is favored in other countries. The chief advantage of carbon is that it attains higher temperatures than graphite because its crystal structure makes it a poorer conductor of both heat and electricity. The main disadvantage of carbon is that it is difficult to machine because of hardness and brittleness. Spindler (*29*) reviewed recent comparisons of the two materials and reported his own observations. One of these was that although use of carbon craters speeded up vaporization of the sample, as expected, mixing of carbon powder with the sample materially slowed the vaporization process.

The problem of fractional distillation should be discussed more specifically. With the direct-current arc, thermal energy is used to vaporize a bulk sample from a crater, enabling low-boiling components to distill off first. The situation is complicated, however, by chemical reactions. For example, a normally volatile compound may react with the

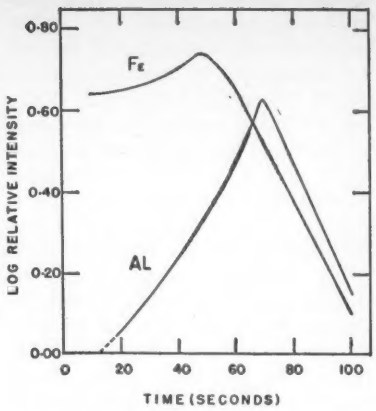


Fig. 2. Vaporization behavior of iron and aluminum from glass sand in a 10-ampere direct-current arc. Note that most of the iron but only a small portion of the aluminum was volatilized during the first 50 seconds. [J. F. Gamble, Rutgers University]

electrode material to form a refractory carbide. Usually, fractional distillation need not be too serious a problem, and it can often be used advantageously, as suggested earlier. Many of the difficulties relative to precision can be eliminated when data on the vaporization behavior of the material being analyzed are at hand (Fig. 2). In view of the ease with which such data can be obtained through jumping-plate studies, failure to obtain such information is inexcusable. Where fractional distillation affords no advantages, it can often be minimized by one of several methods, such as the use of the Stallwood jet. A concise introduction to fractional distillation is given by Ahrens (*30*).

In contrast to the general use of the direct-current arc in agriculture and biology, the high-voltage alternating-current spark is preferred in the field of metallurgy. Four major generalizations account for this: (i) the spark provides better precision than the arc; (ii) metal samples, which are most easily analyzed as self-electrodes, are not melted by the spark; (iii) the sensitivity of the spark, although generally less than that of the arc because of the small amount of sample vaporized, is sufficient for determining most alloying constituents in metals; and (iv) matrix effects are minimized with the spark, although it must not be assumed that they are nonexistent. Recent research on the application of spark excitation to analysis of solutions resulted in significant increases in sensitivity, and this approach now seems very promising as a means of analyzing a great variety of samples. Samples from the area of nutrition research definitely fall within the scope of this technique.

Solution methods can be classified in two general categories: true solution and solution residue. The porous-cup technique developed by Feldman (*31*) is probably the foremost of the true-solution methods. In this technique, a hollow upper electrode with a thin porous bottom is used; the solution slowly percolates through the bottom (Fig. 1*C*). A very informative article on the excitation processes with this type of electrode was published by Feldman and Wittels (*32*). Mitchell and Scott (*33*) found this method very useful for the analysis of soil extracts, and Vallee (*1*) employed it for the analysis of biological tissue. Its major disadvantages are its failure to function well with solutions of high salt concentration and the variable porosity of its electrodes.

Another versatile true-solution method involves the use of a rotating graphite disk that dips into the solution and transports fresh sample on its periphery into the spark-excitation zone (Fig. 1*D*). This method was popularized by Applied Research Laboratories, Glendale, California (*34*). Of particular interest to the nutritionist is the application of this technique by Paolini and Kennedy (*35*), who determined five elements in food products directly, without ashing. An interesting study of the effects of basic variables on excitation was reported by Waggoner (*36*).

Flickinger, Polley, and Galletta (*37*) described a method in which the solution is held in a polyethylene vial cap fitted tightly around a center-post electrode. The solution feeds through a small hole in the outer electrode wall and bathes the center post, which conducts it to the analytical gap by capillary action. A modification of this technique, in which the electrode has a small hole drilled in the top for conduction of the solution, was recently described by Zink (*38*) (Fig. 1*E*). Though very promising, this system has not been adequately evaluated as yet. There are several other true-solution methods of less interest, which I shall not consider here.

In all probability the best-known solution-residue method in which spark excitation is employed is the copper-spark technique of Fred, Nachtrieb, and Tomkins (*39*). Hydrochloric acid solutions of the samples are dried on the ends of high-purity copper rods and excited. The sensitivity obtained, which is comparable to that obtained with the

direct-current arc, was attributed to the ease with which the residue can be excited, due to the fact that it does not penetrate into the copper. There is one major limitation: solvents that react with copper cannot be used. In an attempt to circumvent this limitation Pickett and Hankins (*40*) used graphite electrodes treated with paraffin dissolved in toluene (Fig. 1*F*), but this coating was not impervious to the perchloric acid solutions they wished to use. Morris and Pink (*41*) obtained sensitivities in the low millimicrogram region for several elements evaporated from aqueous solutions containing little or no acid by treating graphite electrodes with Apiezon N grease dissolved in ether. I have since shown (*42*) that good precision and accuracy can be obtained with several different acid solutions, but only when penetration into the electrode is completely eliminated. (Plicene and polyethylene were satisfactory as "acid proofing agents" in most cases.) As a result, the scope of this procedure has been considerably enlarged. Similar considerations apply to the rotating "platrode" developed by Rozsa and Zeeb (*43*), wherein a 0.25-inch graphite disk is substituted as the bottom electrode so that solution volumes up to 0.5 milliliter can be evaporated (Fig. 1*G*). An excellent comparative study of both solution-residue and true-solution methods was published by Baer and Hodge (*44*).

Another approach, somewhat analogous to residue methods, is to mix sample ash with briquetting graphite and mold a pellet under high pressure. Such a pellet becomes an electrical conductor that can be affixed to a supporting electrode. Muntz and Melsted (*45*) used this approach for unashed plant material, but the precision attained was less than is usually required.

Although true-solution methods are often more convenient, the laboratory of the department of soils at Rutgers has been primarily concerned with residue methods. W. J. Hanna of that department suggested that it would be of considerable value to be able to analyze plant tissue and related material containing low levels of radioactive tracers. Analytical data depicting the over-all mineral-nutrition status of a plant should materially aid in the interpretation of tracer behavior. Of the several methods discussed, the solution-residue method, with 0.25-inch electrodes, is best adapted to this problem because of its small heat production, its cleanliness and simplicity, and its utilization of samples of minimum size. Such a discharge can readily be enclosed, and the small amount of gaseous material produced can be scrubbed and monitored for radioactivity.

Jarrell (*8*) presented some simplified circuit diagrams of instruments that have been used to generate spark discharges and discussed the principles involved. Of special interest is the electronically controlled spark, by which Bardocz (*46*) was able to greatly reduce continuous background and air lines by preventing radiation from the first 10 microseconds of each gap breakdown from entering the spectrograph. In combination with those solution techniques that can be used over long exposure times, a sharp reduction in background might possibly result in appreciable increases in sensitivity.

Vaporization and excitation processes in spark discharges are extremely complex and are not completely understood. Feldman (*47*) described the mechanism of the spark as the ejection of material from the sample into the discharge, "shot-gun style." Braudo, Craggs, and Williams (*48*) and Feldman and Wittels (*32*), among others, reported on temperature studies, but the nature of the discharge was a complicating factor. Perhaps the most comprehensive report on the fundamentals of excitation in the spark was that of Mandelstam (*49*). Further breakthroughs may result when more work has been done on time-resolved spectra with the Bardocz or similar sources.

Resolution of Emitted Radiation

Many successful arrangements with prisms or gratings have been developed for resolving emitted light into its component wavelengths. This problem has too many aspects to be thoroughly discussed here, and it would be presumptuous of me to consider any one system to the exclusion of others. I shall present only a few points of special interest in biological analysis [for a description of fundamentals, see Sawyer (*50*)].

One of the most important requirements of a spectrograph is adequate dispersion, usually expressed as the reciprocal linear dispersion in angstroms per millimeter, on the photographic plate. This expression is unfortunate in that higher values represent less dispersion—that is, more crowding of lines. According to Mitchell (*24*), "It is in general not the elements to be determined, but the source to be used and the composition of the material to be examined, in so far as its major constituents are concerned, which decide the instrument to be used." As the number of lines produced by the major components increases, the reciprocal linear dispersion must decrease, so that lines from the matrix material will not interfere with analytically important lines. Since biological matrices generally give rise to spectra with only a moderate number of lines, most spectrographs have sufficient dispersion.

Sensitivity is directly related to dispersion. Line-to-background ratio is most often the factor limiting sensitivity. This ratio increases as the reciprocal linear dispersion decreases, because the same amount of background is spread over a larger area while the line remains unaffected. Jarrell (*50*) emphasized that this increase in sensitivity occurs only up to the critical dispersion at which the slit and line widths are equal. Further reduction in the reciprocal linear dispersion actually decreases line-to-background ratio. Figures 3 and 4 illustrate these relationships.

A second factor of particular interest is speed, which we can approximately define as light yield. Mitteldorf (*52*) pointed out that speed is the most important factor in the analysis of micro samples, whereas in the determination of trace elements in large samples, line-to-background ratio is the limiting factor. Speed is also limiting for very volatile elements. The relative speed of spectrographs is normally inversely proportional to the squares of their effective *f*-numbers. Unfortunately, low *f*-number and low reciprocal linear dispersion are mutually exclusive, since the small spectrograph required for low *f*-number results in a large reciprocal linear dispersion. Nevertheless, instruments of low *f*-number should be increasingly useful, particularly in combination with such external devices as inert atmospheres that lower the background, for determining such volatile elements as arsenic, mercury, and selenium. The use of gratings blazed for a specific wavelength can also increase speed appreciably.

Recording Spectral Lines

Of the problems attendant on the use of photographic emulsions, photographic speed merits special mention. Eastman 103-0 plates are very high

speed plates and are especially useful in those cases where background can be minimized. With large samples it is often better to use a plate of moderate speed, such as Spectrum Analysis No. 1, to take advantage of the fine grain and high contrast, which contribute to good precision.

Direct photoelectric recording of spectral intensities is much faster and considerably more precise than photographic recording. But direct readers are very expensive and lack the flexibility often required of a research instrument. Despite this, in the last 5 years several direct readers have been installed in laboratories responsible for the analysis of large numbers of biological and agricultural samples. Instruments that are interconvertible as either direct readers or photographic instruments are available and would seem to afford the best solution to the problem of analyzing both large numbers of routine, and lesser numbers of nonroutine, samples.

Interpretation

Quantitative optical emission spectrochemistry depends on the conversion of measured intensities or intensity ratios to concentrations by means of a calibration curve established from several standard samples. The lack of primary standards for biological and agricultural materials is, therefore, a problem of utmost concern. X-ray fluorescence, colorimetry, and many other techniques are plagued by this same difficulty. The use of secondary standards that have been analyzed by other methods presents many problems. If samples are analyzed by only one laboratory, the likelihood of serious bias exists, and when several laboratories participate in a standardization program, there is seldom good agreement in analytical data, particularly for trace elements. The heterogeneity of this type of sample material undoubtedly contributes heavily to this variability. As a result, most optical emission spectrochemistry laboratories synthesize their own standards from high-purity chemicals. In this connection, solution methods have the advantage of homogeneity, a property that is difficult to achieve with powder standards, which are likely to fractionate on standing because of differences in particle size and density and because of electrostatic effects.

If availability of satisfactory standards, is assumed, there still remains the necessity to maintain close control over calibration curves, which are subject to shifts caused by environmental and other factors. It is common practice in many laboratories to expose one or more standards along with samples on the same photographic plates. Original calibration curves are then shifted to fit these new but very limited numbers of points. I have for some time been employing a statistical-control approach that has distinct advantages over other methods.

Another important aspect of calibration is critical matching of analysis and internal standard-element lines. If possible, all lines selected should be free from self-reversal. In most cases, they must be free of interference by lines of other elements, although satisfactory corrections can occasionally be applied. Matched lines should (i) be similar in volatilization behavior, (ii) be as close as possible in excitation potential, (iii) be from elements of similar ionization potential, and (iv) be reasonably close in wavelength. Some compromises are necessary in general-purpose methods for analyzing several elements, but insofar as possible these criteria should be met.

One further problem in the interpretation of trace-element analyses is contamination from reagents, electrodes, air, and miscellaneous sources. Contamination can never be completely eliminated, but complete elimination is

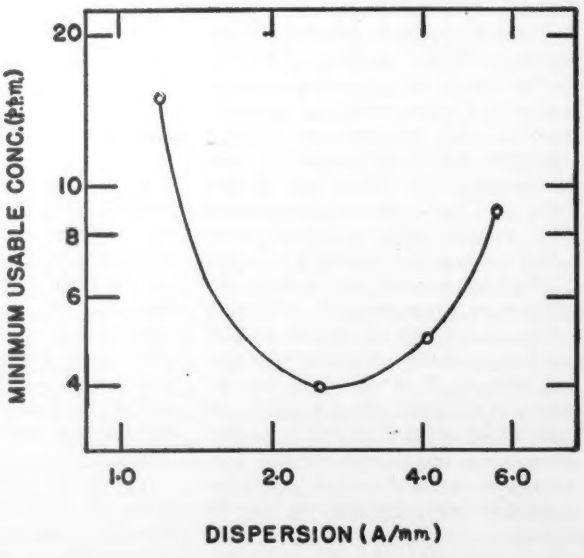


Fig. 3 (left). Variations of spectral line and background intensities with dispersion, for a slit width of 20 microns. Fig. 4 (above). Sensitivity-dispersion relationships for the determination of cadmium in zinc. [Both figures courtesy Jarrell-Ash Co., Newtonville, Mass.]

the goal the investigator should strive for. For this purpose, direct procedures, involving a minimum of reagents and the shortest possible time lapse from start to finish, are most favorable. Contamination problems start at the moment of sample collection. Too frequently the information sought from a sample has been invalidated before the sample ever reaches the laboratory. Disposable polyethylene gloves and containers are quite helpful in this regard.

Application in Nutrition Research

Both plants and animals require many different nutrient elements, a number of them in trace amounts. Since the concentration of each of these elements is in part dependent on the levels of one or several of the others, thorough diagnosis of nutritional status cannot be made on the basis of information on three or four elements. The value of an analytical scheme providing data on many elements in a small sample becomes obvious.

In the area of plant nutrition, many data have been accumulated on trace-element concentrations in various plants grown on a variety of soils. These data are far too extensive for detailed discussion here, but they have afforded a basis for detecting deficiencies or toxicities, or both, of certain elements in some plants, and they often make it possible to demonstrate lack of balance between elements. Much of this work has been concerned with forage crops, because the requirements of many animals for such elements as cobalt are fairly well established. Nutrient-element composition of fruit-tree leaves has been studied with optical emission spectrochemistry by Kenworthy (*53*) and others in an attempt to establish reliable concentration ranges for many elements in trees not showing evidence of a deficiency or an excess. Influences of climate, age of plant, season, location, and many other factors greatly complicate this situation. Bradford and Harding (*54*) reported variations of as much as 50-fold in the minor-element contents of orange-tree leaves sampled from high-yielding orchards. They suggest that sampling be carried out annually in order that any long-term trends may be detected, and this may be the only workable solution to this problem. At present, optical emission spectrochemistry is the method best adapted to the handling of such a program.

So far, little progress has been made toward evolving analytical procedures for estimating the supply of minor elements on the basis of amounts of "available" nutrients in the soil. The work of Mitchell and Scott (*24, 33*) and that of Pickett and Dinius (*55*) give an idea of the degree of success achieved. Despite the slow rate of progress, expansion of this work is justifiable in view of the need for better control of crop production to optimize economic return. It is conceivable that soils not now deficient in trace elements may become so in the near future. To carry out preventive fertilization, deficiencies of these elements must be detected during the incipient stages. For success in this endeavor, periodic analyses of many samples for many elements must be made.

The mineral-nutrient content of foods consumed by human beings is also of interest. Hopkins and Eisen (*56*) have demonstrated the feasibility of applying optical emission spectrochemistry to the analysis of fresh vegetables from urban markets. Such information may eventually be related to the geographical distribution of conditions of malnutrition and to distribution of certain diseases, although the varied diet of human beings probably makes such a connection less likely in man than in domestic animals. These studies also provide an index of contamination by spray residues containing copper, zinc, arsenic, or other elements.

Metal-binding in medicine is being studied quite intensively (*57*), and optical emission spectrochemistry is being applied to a considerable extent in this research. Patterns of excretion of trace metals and the change in these patterns upon infusion of chelating agents has been investigated. The work of Perry and Perry (*58*) with ethylenediaminetetra-acetic acid is an example of a study in which optical emission spectrochemistry was advantageously employed.

Vallee (*1*) has investigated subcellular fractions of animal organs by this method, in studies wherein ability to obtain a maximum amount of information from a sample of minimum size was essential. Far more insight into basic biological functions was obtained from a study of individual fractions than would have resulted from analyses of the total material. As biochemical separations are further refined, ever-smaller samples will be available for analysis. Optical emission spectrochemistry should make a major contribution to the furtherance of this research.

In conclusion, it appears that intelligent and imaginative application of this technique to nutrition research can be most rewarding, although other techniques offer greater advantages in the study of some problems. But any laboratory performing multiple trace-element determinations will find that a good spectrograph is a tool of extreme versatility and capability when manned by a competent spectrochemist.

References and Notes

1. B. L. Vallee, in "Spectrochemical analysis for trace elements," *ASTM Spec. Tech. Publ. No. 221* (1957), pp. 47–57.
2. This article is a paper of the journal series, New Jersey Agricultural Experiment Station, Rutgers, the State University, Department of Soils, New Brunswick. I wish to thank F. E. Bear, R. B. Alderfer, and W. J. Hanna for helpful suggestions.
3. J. R. Churchill, *Ind. Eng. Chem., Anal. Ed.* **16**, 653 (1944).
4. L. W. Strock, *Spectrochim. Acta* **1**, 117, 123 (1939).
5. M. Slavin, *Ind. Eng. Chem., Anal. Ed.* **10**, 407 (1938).
6. C. E. Harvey, *Spectrochemical Procedures* (Applied Research Laboratories, Glendale, Calif., 1950).
7. W. Gerlach, *Z. anorg. u. allgem. Chem.* **142**, 383 (1925).
8. R. F. Jarrell, in *The Encyclopedia of Spectroscopy*, G. L. Clark, Ed. (Reinhold, New York, 1960), pp. 158–169.
9. L. W. Strock, in *Trace Analysis*, J. H. Yoe and H. J. Koch, Jr., Eds. (Wiley, New York, 1957), pp. 346–397.
10. W. F. Meggers, *Spectrochim. Acta* **3**, 1 (1947).
11. J. W. Robinson, in *The Encyclopedia of Spectroscopy*, G. L. Clark, Ed. (Reinhold, New York, 1960), pp. 337–343.
12. M. F. Meggers, *J. Opt. Soc. Am.* **31**, 39 (1941).
13. M. R. Baker and B. L. Vallee, *ibid.* **45**, 773 (1955).
14. B. L. Vallee and A. F. Bartholomay, *Anal. Chem.* **28**, 1753 (1956).
15. P. T. Gilbert, Jr., *Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy* (1961).
16. J. A. Dean, *Flame Photometry* (McGraw-Hill, New York, 1960).
17. J. H. Gibson and W. D. Cooke, *Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy* (1961).
18. N. W. H. Addink, in *Proc. Intern. Conf. Spectroscopy, 6th Conf., Amsterdam, 1956* (1957), pp. 168–178.
19. O. S. Duffendack and J. M. LaRue, *J. Opt. Soc. Am.* **31**, 146 (1941).
20. O. Leuchs, *Spectrochim. Acta* **4**, 237 (1950).
21. A. J. Mittledorf, *The Spex Speaker* (Spex Industries, Inc.) **6**, No. 1 (1961).
22. R. Mannkopff and C. Peters, *Z. Physik* **70**, 444 (1931).
23. L. W. Strock, *Spectrum Analysis with the Cathode Layer Method* (Hilger, London, 1936).
24. R. L. Mitchell, "Spectrographic analysis of soils, plants and related materials," *Commonwealth Bur. Soil Sci. (Gt. Brit.) Tech. Commun. No. 44* (1948).
25. B. L. Vallee, C. B. Reimer, J. R. Loofbourow, *J. Opt. Soc. Am.* **40**, 751 (1950); B. L. Vallee and S. J. Adelstein, *ibid.* **42**, 295 (1952); B. L. Vallee and R. W. Peattie, *Anal. Chem.* **24**, 434 (1952); S. J. Adelstein and B. L. Vallee, *Spectrochim. Acta* **6**, 134 (1954); B. L. Vallee and M. R. Baker, *J. Opt. Soc. Am.* **46**, 77 (1956); B. L. Vallee and R. E. Thiers, *ibid.* **46**, 83 (1956); M. R. Baker, S. J. Adelstein, B. L. Vallee, *ibid.* **46**, 138 (1956); R. E. Thiers and B. L. Vallee, *Spectrochim. Acta* **11**, 179 (1957).
26. R. L. Rupp, G. L. Klecak, G. H. Morrison, *Anal. Chem.* **32**, 931 (1960); G. H. Morrison, R. L. Rupp, G. L. Klecak, *ibid.* **32**, 933 (1960).

27. B. J. Stallwood, *J. Opt. Soc. Am.* **44**, 171 (1954).
28. A. J. Mitteldorf, *The Spex Speaker* (Spex Industries, Inc.) **2**, No. 3 (1957).
29. D. C. Spindler, *Appl. Spectroscopy* **15**, 20 (1961).
30. L. H. Ahrens, *Spectrochemical Analysis* (Addison-Wesley, Cambridge, Mass., 1950).
31. C. Feldman, *Anal. Chem.* **21**, 1041 (1949).
32. ——— and M. K. Wittels, *Spectrochim. Acta* **9**, 19 (1957).
33. R. L. Mitchell and R. O. Scott, *Appl. Spectroscopy* **11**, 6 (1957); R. L. Mitchell, *Soil Sci.* **83**, 1 (1957).
34. *Spectrographer's News Letter* **2**, No. 9 (1948).
35. A. Paolini, Jr., and R. M. Kennedy, *Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy* (1961).
36. C. A. Waggoner, "Some factors influencing excitation in spectrochemical solution analysis," *Pacific Naval Lab. Esquimalt, B.C., Tech. Mem. No. 58-8* (1958).
37. L. C. Flickinger, E. W. Polley, F. A. Galletta, *Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy* (1958).
38. T. H. Zink, *Appl. Spectroscopy* **13**, 94 (1959).
39. M. Fred, N. H. Nachtrieb, F. S. Tomkins, *J. Opt. Soc. Am.* **37**, 279 (1947).
40. E. E. Pickett and B. E. Hankins, *Proc. Am. Assoc. Spectrographers, Chicago* (1953).
41. J. M. Morris and F. X. Pink, in "Spectrochemical analysis for trace elements," *ASTM Spec. Tech. Publ. No. 221* (1957), pp. 39–46.
42. C. L. Grant and W. J Hanna, *Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy* (1960); C. L. Grant and W. J. Hanna, *Proc. Annual Meeting Assoc. Offic. Agr. Chemists, Washington* (1960); C. L. Grant, *Proc. Soc. Appl. Spectroscopy* (1961); C. L. Grant, *Anal. Chem.* **33**, 401 (1961).
43. J. T. Rozsa and L. E. Zeeb, *Petrol. Processing* **8**, 1708 (1953).
44. W. K. Baer and E. S. Hodge, *Appl. Spectroscopy* **14**, 141 (1960).
45. J. H. Muntz and S. W. Melsted, *Anal. Chem.* **27**, 751 (1955).
46. V. A. Bardocz, *Appl. Spectroscopy* **11**, 167 (1957).
47. C. Feldman, in *Trans. Florida Seminars on Spectroscopy, 1955–1957* (1958), vol. 12, No. 11, pp. 24–35.
48. C. J. Braudo, J. D. Craggs, G. C. Williams, *Spectrochim. Acta* **3**, 546 (1949).
49. S. Mandelstam, *ibid.* **15**, 255 (1959).
50. R. A. Sawyer, *Experimental Spectroscopy* (Prentice-Hall, New York, 1944).
51. R. F. Jarrell, in *The Encyclopedia of Spectroscopy*, G. L. Clark, Ed. (Reinhold, New York, 1960), pp. 243–263.
52. A. J. Mitteldorf, *ibid.*, pp. 308–316.
53. A. L. Kenworthy, in *Proc. Am. Soc. Hort. Sci.* **55**, 41 (1950).
54. G. R. Bradford and R. B. Harding, *ibid.* **70**, 252 (1957).
55. E. E. Pickett and R. H. Dinius, "Trace elements in Missouri soils," *Missouri Agr. Expt. Sta. Research Bull. No. 553* (1954), pp. 1-20; E. E. Pickett, "Mineral composition of Missouri feeds and forages: *Lespedeza*," *ibid., No. 594* (1955), pp. 1-24.
56. H. Hopkins and J. Eisen, *Agr. and Food Chem.* **7**, 633 (1959).
57. *Metal-Binding in Medicine*, M. J. Seven and L. A. Johnson, Eds. (Lippincott, Philadelphia, 1960).
58. H. M. Perry, Jr., and E. F. Perry, *J. Clin. Invest.* **38**, 1452 (1959).

INSTRUMENTS AND TECHNIQUES

New Method for Heart Studies

Continuous electrocardiography of active subjects over long periods is now practical.

Norman J. Holter

Electrocardiography today is an indispensable tool for physiologist and physician. Cardiac electrophysiology began in 1887 when Ludwig and Waller first noted changing chest potentials, and practical electrocardiography began in 1893 with Einthoven's string galvanometer work. Then followed the body of classic work in this field, but the electrocardiograph did not find wide use until the advent of modern direct-writing instruments. Today's clinical instrument is convenient and dependable and will remain an important tool in research and in examinations of established heart conditions. It is still only a hit-or-miss affair for studying long-period heart action or detecting transient heart aberrations.

Until recently, electrocardiography required connecting leads from subject to instrument. This was no handicap in building present-day principles but has been a handicap in studying active subjects. Leads can be detached during exercise and reconnected later, and with special electrodes some exercise is feasible during recording. However, considerably more physical freedom is desirable if one is to learn more about the heart under realistic conditions of daily life.

This article reports a series of concepts and developments concerned with obtaining long-period continuous electrocardiographic records from active subjects in order to obtain data which constitute a statistically valid sample of heart action under conditions that give the subject the greatest possible freedom of activity. This goal automatically generates the problem of handling, in a convenient and practical way, the very voluminous data acquired. No one can adequately examine 100,000 continuous ordinary electrocardiograms (24-hour recording at a pulse rate of 70). A number of early ideas have led to the concept of breaking away from the limitations of orthodox electrocardiography to solve the scientific problem of adequate sampling and the medical problem of obtaining electrocardiograms in situations other than the highly artificial and unrealistic situation of resting quietly on a comfortable pad after a good sleep, with no breakfast, and with calm confidence in one's physician.

In 1939 J. A. Gengerelli and I became interested in remote stimulation of physiological systems as means for minimizing interference with the system. By modifying a classic experiment, we produced contractions of frog muscle by stimulating its nerve supply by means of a changing electric field without electrodes or connecting wires (*1*). This raised the converse question of whether an external field is created by a nerve impulse. From these two basic and converse ideas developed a series of studies leading, on the one hand, to the remote stimulation of the brain of the intact animal and a study of corresponding behavior (*2, 3*) and, on the other hand, to the use of radio for the accurate transmission of electroencephalograms and electrocardiograms from freely exercising subjects (*4, 5*). With the electronics of 1942, a nerve impulse field was not detected (*2*), but recently we obtained evidence for the existence of such a field (*6*). Radioelectrocardiography as a practical and convenient technique is now becoming relatively routine; its first clinical application was by MacInnis in 1954 (*7*).

Steps toward Freedom

Up to this point there has been developed only what I would call an initial step toward freedom—the elimination of entangling wires. Moreover, while telemetering per se does provide greater freedom of action, it does not provide practical long-period continuous electrocardiography. It also requires an in-

The author is president of the Holter Research Foundation, Helena, Montana. This article is based on a paper presented 20 July 1961 at the 4th International Conference on Medical Electronics, New York.

dividual to remain within range of radio receiving and electrocardiographic observing equipment and has the disadvantage of being subject to occasional radio interference. W. R. Glasscock and I therefore developed a portable radio-receiver tape-recording unit, to be carried by a subject free to go where he wished as long as he took the "ECG brief case" and left it in his general environment (*8*). Still needed, however, was freedom from such baggage and from radio interference, plus means of rapidly studying the long magnetic tapes obtained. We therefore developed the "electrocardiocorder," which eliminates radio circuits at both ends and, when used with rapid-analysis instruments developed for the purpose, achieves what I call full freedom (9). This means freedom from connecting wires, freedom from the restriction of staying in one locality, freedom from the inconvenience of carrying electronic baggage, and freedom to make records of any desired length and still be able to analyze them. Thus the sequence of concepts progressed from remote stimulation of nerves to the hardly anticipated stage of our next efforts—the study of the heart action of swimmers, forest fire fighters, bronco riders, and so on.

Beginning steps are illustrated in Fig. 1 (top), which shows our current radioelectrocardiograph system; the "electrocardiocaster" is held in the hand, and the radioelectrocardiograph receiver, demodulator, oscilloscope, and clinical electrocardiograph are at the right—a useful system when we need to make observations at the exact moment of the heart beat. The lower part of Fig. 1 shows our ECG brief case in use; a subject is eating in a restaurant while an electrocardiocaster in his upper coat pocket sends data to the unit on the small table by the wall. This system is also one step toward truly long-period continuous electrocardiography, because magnetic tape storage in the unit replaces spot observation on an oscilloscope or on electrocardiograph paper. I define "long-period" as longer than a half hour, the usual limit for one roll of ordinary electrocardiograph paper.

The electrocardiocorder is shown in Fig. 2. It is a small portable unit containing voltage amplifier, power amplifier, oscillator, mixer, temperature compensator, recording heads, motor control, drive mechanism, batteries, tape and reels, case, switches, and connectors. It is oval, measures 19.5 by 9.8 by 4.6 centimeters, weighs 1 kilogram, and

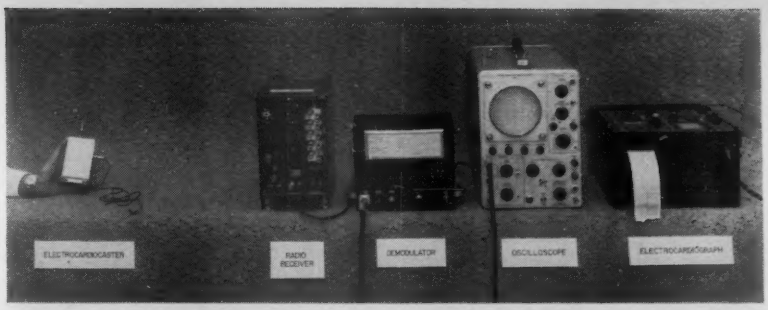


Fig. 1. (Top) Laboratory radioelectrocardiograph system; (bottom) portable version in use.

is conveniently carried in a man's coat pocket or a woman's strap-type handbag, or is fastened to the chest during unusual physical activity. The power supply is adequate for 80 to 100 hours of operation, and the tape capacity is 10 hours; after 10 hours the tape is changed for longer tests. Our latest model just completed 1000 hours of total operation without failure. The woman shown in Fig. 3 is walking uphill after working 8 hours. The tape, of 10-hour capacity, provides a continuous record of all heartbeats from 1 hour before to 1 hour after her workday. Chest leads, approximately V_4 leads, are used.

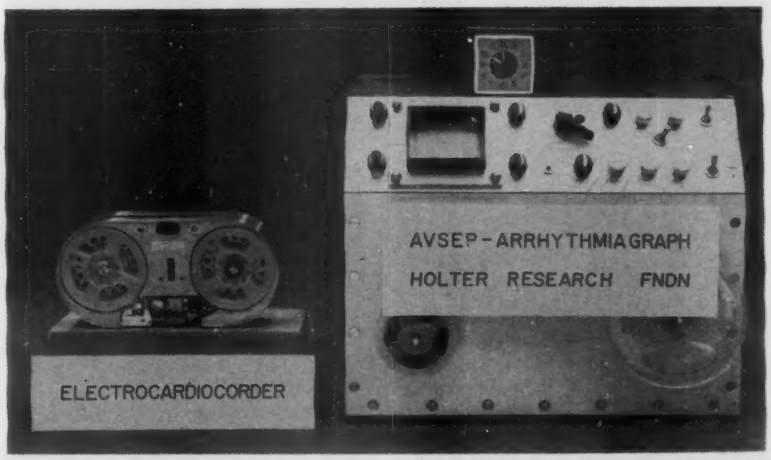


Fig. 2. The recorder-analyzer system for long-period continuous electrocardiography of active subjects and rapid analysis of the resulting voluminous data.

AVSEP-Arrhythmiagraph Analyzer

Long records are useless without means of rapidly locating parts of interest; this is accomplished by the analysis part of the system. Changes in form are detected by "AVSEP" (an abbreviation for "audio visual superimposed electrocardiogram presentation"); the arrhythmia detector is described later. A crude model of the analyzer described in 1957 (*5*), was a floor-rack assembly, but the model shown in Fig. 2 is as portable as an ordinary electrocardiograph. In operation, electrocardiocorder tapes move at relatively high speed and present the signals on an oscilloscope, each electrocardiogram being rapidly superimposed upon its predecessor. Electrocardiograms which are continuous duplicates of each other thus appear as a single, relatively steady electrocardiogram, as shown in Fig. 4 (top). This is a 1-second photograph of the AVSEP screen; during this period, 80 electrocardiograms were displayed. The signals are also presented aurally, as a noisy growl in the low audio region; and the ear notes any change in the nature of this noise, thus adding to the over-all sensitivity of the method. If only one electrocardiogram differs significantly, the change will be seen and heard. During complicated heart attacks the "single" dynamic electrocardiogram pattern of AVSEP appears much like a snake writhing about, showing details of the attack and of its approach and termination.

The tape, run at 60 times the recording speed of 7½ inches per minute, provides two signals from the recording heads, which are mechanically displaced so that AVSEP will begin with the *P* wave rather than the *R* wave used to trigger the sweep. One signal goes through an amplifier stage, through an integrator (to correct reproducing-head distortion), through another amplifier, and to the AVSEP speaker and oscilloscope. The alternate signal goes through an amplifier stage, a clipper-filter stage, and a delay-trigger stage, becoming a sawtooth signal for the horizontal AVSEP sweep; it goes also to a separate oscilloscope (Fig. 5, bottom) to form the arrhythmiagram. A 10-hour record can be examined in 10 minutes; a synchronized clock tells the observer the time of day for any part of the tape, so changes can be correlated with activity. Myographic potentials, when present, rarely interfere because the AVSEP pattern is regular and the unwanted signals are purely random.

Fig. 3. The electrocardiocorder in use, carried in a handbag. The chest leads run down the strap.

The arrhythmiagraph part of the analysis unit presents rapid, quantitative, compact information on pulse irregularities, whereas AVSEP is used to observe changes of form. (Changes in pulse time, the *R-R* interval, are seen on AVSEP only as a rapidly changing tail on the electrocardiogram.) The arrhythmiagraph idea (*10*), which may or may not be new with us, is illustrated schematically in Fig. 6 (top). The diagram shows the conversion of each *R-R* interval to a vertical line whose length is proportional to pulse time; compression of the pattern into a small space; and the resulting prominence of two arrhythmias. (Actually, a premature beat results in a short vertical line, and it is the long line, representing the compensatory pause, that stands out most prominently.) In a test on a certain very long ordinary paper record, 2 hours of a technician's time were required to establish with confidence the existence of 16 premature systoles, whereas the same quantitative result was obtained from the corresponding arrhythmiagram in 6 seconds. Typical arrhythmiagrams are also shown in Fig. 6 (middle and bottom). Premature systoles may be seen; the bottom record is from a subject with an extremely heavy work load, mental and physical fatigue, and inadequate sleep, who had drunk a considerable amount of coffee.

Electrodes

There have been occasional innovations in the design of electrodes for orthodox electrocardiography—innovations in shape, size, and material and in holding devices (elastic straps, suction cups, and so on)—but little attention heretofore has been paid to problems that arise with use over long periods. Such problems are changes in impedance, patient comfort, dermatitis, effects

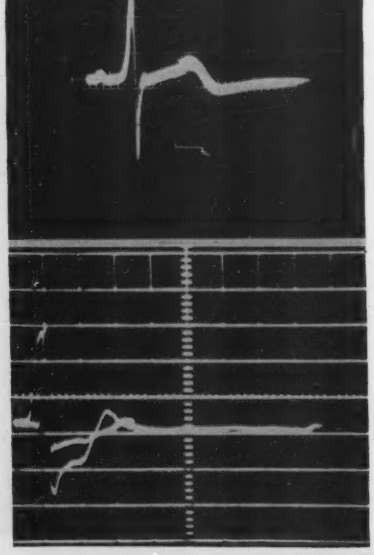


Fig. 4. (Top) Normal AVSEP pattern; (bottom) pattern of a bigeminy attack.

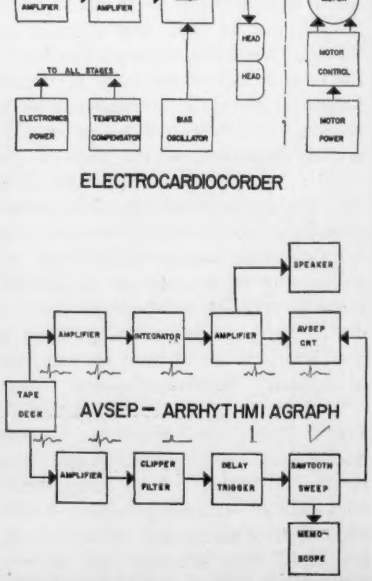


Fig. 5. Block diagram of the recorder-analyzer system.

of moving wires, and so on. With the advent of long-period continuous electrocardiography, various modifications of the usual methods can be introduced, although more work remains to be done. I do not intend to give a comprehensive review, but interested readers can check some references (*11*) and, with a little experience, can readily select something suitable for a particular purpose. Relatively simple methods will suffice in some cases—for example, flat electrodes with the usual paste, held on the chest by small balls of cotton and strips of paper masking tape. An Ace bandage around the chest provides added support. More elaborate methods are needed for recording periods of several hours to several days; it is my present opinion that the best long-period electrodes will be some form of the so-called fluid-type assembly, with electrodes supported some distance from the skin in a manner to seal a suitable electrolyte between electrode and skin. Glasscock proposes carbon electrodes in such assemblies; his preliminary tests show minimal artifacts from motion.

Medical Uses of the System

The electrocardiocorder-AVSEP-arrhythmiagraph system may be used both in clinical research and in routine medical practice. A discussion of medical uses of necessity includes research uses, since routine use of the system at this time often uncovers new facts on heart action. Many individuals come to autopsy without having had either symptoms or treatment of what are found to be heart lesions of a type which would have shown on an electrocardiogram. The problem of asymptomatic heart disease is intriguing and important, both clinically and academically (*12*). As stated in the introduction, orthodox electrocardiography will always have its uses in the measurement of established heart conditions, but it does not provide an accurate sampling of all-day heart activity any more than the analysis of a single rock provides an accurate sample of a mountain of ore. Through AVSEP and arrhythmiagraphic analysis of a long electrocardiocorder record, there is a far better chance of finding heart difficulties at an early stage. According to one authority more than half the individuals who have serious arrhythmias are not aware of them (*13*), and some sudden deaths are deaths from arrhythmia that does not result from coronary occlusion. A thorough modern physical examination takes parts of several days of the patient's time, and I suggest that routine recording with a electrocardiocorder for a suitable interval be included, for the possible detection of any subclinical angina, potentially serious arrhythmias, or other transient heart disorders. A large clinic might have a number of electrocordiocorders in use and one analyzer for examining the results. The effects of drugs or other therapy on electrocardiagraphic form and pulse anomalies can be followed quantitatively.

Figure 7 is an electrocardiographic record (of research and clinical interest) of one of our laboratory subjects at the end of a long attack of paroxysmal tachycardia. The heart had started beating at twice the normal rate 8 hours earlier, and the usual medical measures

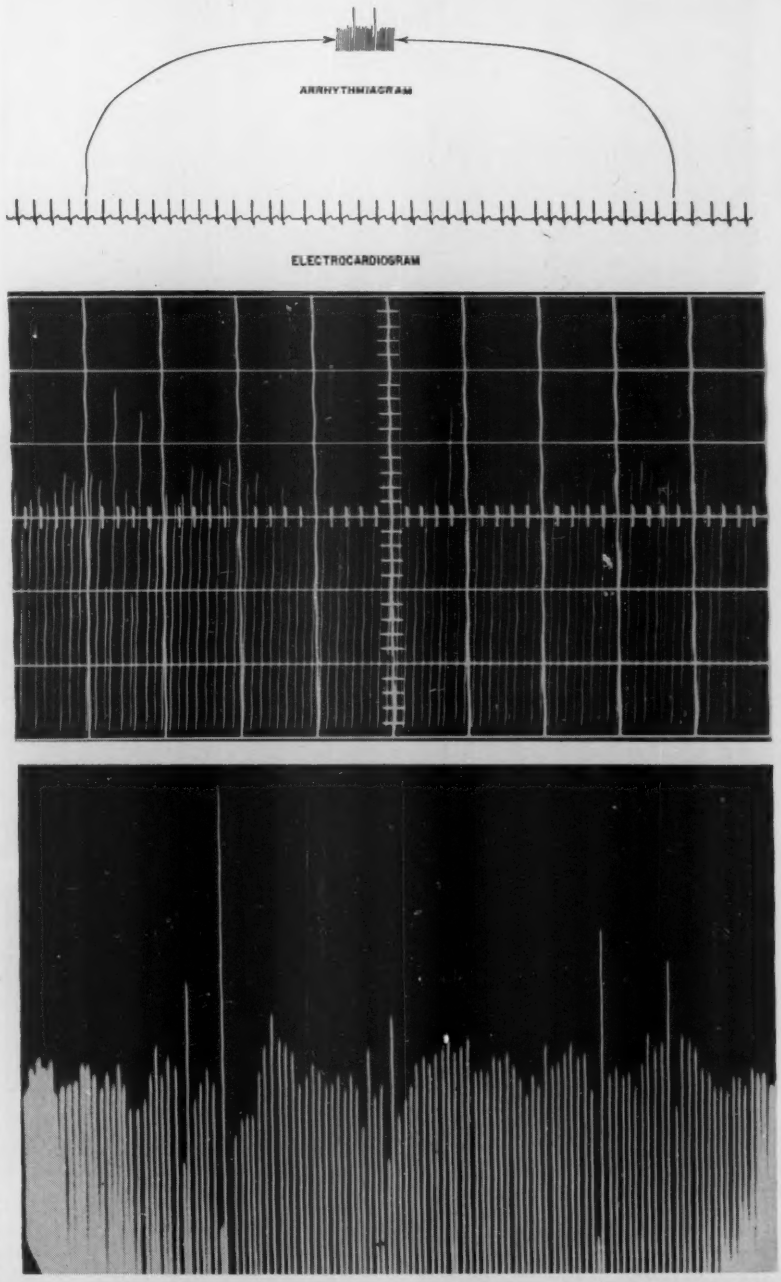
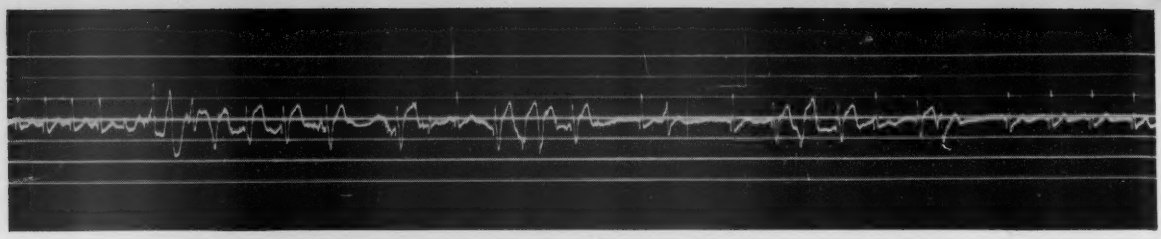
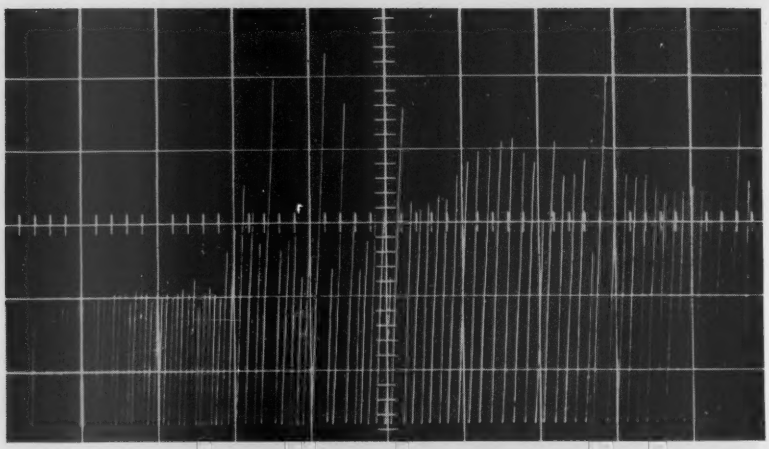
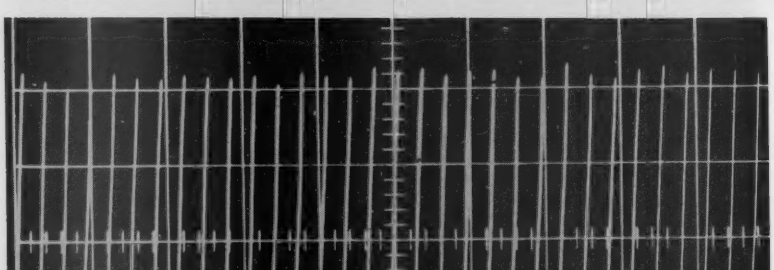
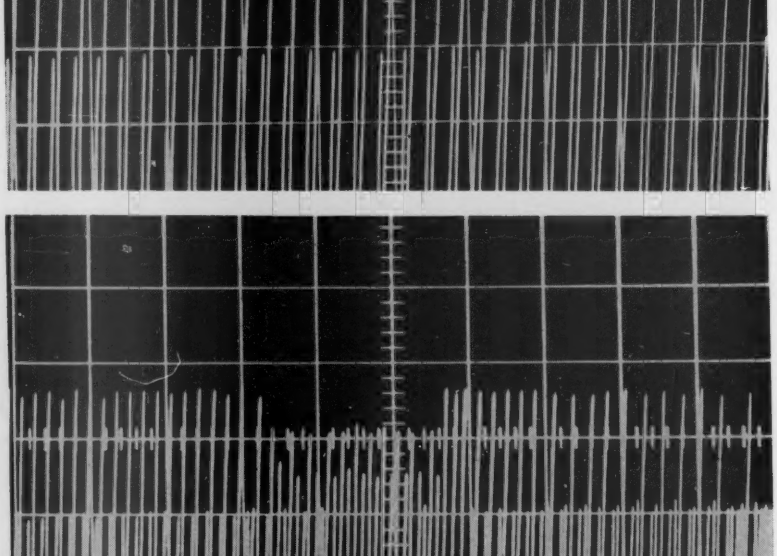


Fig. 6. (Top) Schematic drawing of the arrhythmiagraph; (middle and bottom) typical arrhythmiagrams, showing pulse time variability, including premature systoles.









had not corrected it. The attack later terminated spontaneously, and Fig. 7 shows the complex details of the transition to normal. Figure 8 (top) shows the pulse time details.

I have lent the recorder-analyzer equipment to Dr. John S. Gilson of Great Falls, Montana, who has made records of some 200 clinical cases (*14*). One interesting case is that of a man who, in one occupation, had clinical symptoms of angina pectoris, for which electrocardiographic confirmation could not be obtained. Later, in a different occupation, this individual had no subjective symptoms of angina, but an electrocardiocorder record showed definite anginal changes on AVSEP.

Figure 4 (bottom) reveals a transient attack of bigeminy, a phenomenon in which alternate heart beats differ greatly, both in electrocardiographic form and pulse time. Figure 4 shows two separate electrocardiograms from one heart.

The dynamic nature of the AVSEP pattern is shown in Fig. 9, a series of moving picture frames showing the magnitude of the changes in the AVSEP pattern of a man during an angina attack brought on by lifting heavy boxes in his occupation. On AVSEP this is seen as a single electrocardiogram which begins to "writhe about" as changes occur. Note the great drop in the *S-T* segment of frame No. 7 as compared with frame No. 1. The patient felt pain and took nitroglycerine, and the electrocardiogram returned to what was normal for him. This record enabled Gilson to confirm a questionable diagnosis.

Other arrhythmiagrams of clinical situations are shown in Fig. 8. In the center is the arrhythmiagram of the patient having the bigeminy attack of Fig.

Fig. 7 (above). Detail of an electrocardiogram during termination of paroxysmal tachycardia. Note the high pulse at left and the normal pulse at right. Fig. 8 (left). Arrhythmiagrams of (top) paroxysmal tachycardia at the moment of return to normal and (middle and bottom) of other hearts, showing bigeminy and multiple pulse times.

4. At the bottom, a heart "can't decide" what pulse rate to settle down to; there are several fairly regular pulse times from the same heart. The acoustic effect is interesting in many of these cases; a signal which often sounds like a motor boat suddenly sounds like an entirely different motor boat as anomalies occur.

Two of Gilson's subjects equipped with the unit have been involved in automobile accidents; in each case the patient and equipment survived, but the accident precipitated an angina attack in one subject. One of our subjects, a nervous individual, accidentally violated a traffic law while equipped with the unit and was stopped by the police. The story has an unhappy ending scientifically, for the unit had run out of tape a few minutes earlier. However, this illustrates the kind of real-life situations in which heart studies can be made.

Research Uses

We need to learn more about heartbeat phenomena and the mechanism of production of certain types of electrocardiograms, especially under conditions not measurable by traditional methods. An isolated heart beats very regularly, and all pulse times are equal. Dissected-out parts of suitable hearts beat by themselves at steady rates characteristic of the heart region. However, when the heart is not isolated, outside influences disturb the steadiness seen in the isolated heart. Thus two individuals may each have an average pulse rate of 70 per minute; then why do the two individuals arrive at this average by entirely different routes? Are these variations truly random? What produces them? Is a given variability pattern characteristic of one individual, and does its frequency distribution pattern change and, if so, why? The principle of biological variability is well illustrated when an ounce of alcohol rapidly eliminates a "forest" of premature systoles in the arrhythmiagram of one individual and increases them in another. The quantitative effects of nicotine, caffeine, alcohol, fatigue, tension, and so on, have been easily measured from arrhythmiagrams, hence much new pharmacological research can be conducted with these tools. What I call pulse microstructure needs detailed exploration and statistical analysis, possibly with both our recorder-analysis system and a digital computer. We might profitably use one data-reduction machine to examine the data provided by another data-reduction machine.

In 1957 (5) I suggested that significant electrocardiographic changes might occur during the normal active day of a clinically normal individual. We now have good reason to feel that changes of considerable magnitude do occur in normal people, and we propose use of the electrocardiocorder to better understand the correlation of heart activity with eating, exercise, sexual and other emotional activity, fatigue, sleep, and so on.

The recorder-analyzer combination might be adapted for the study of physiological phenomena other than those of the heart. Some physiological tests already provide data which have been "integrated" over a period of time, so that little would be gained by continuous recording. This is illustrated by a single test for sugar in the urine. If such a test is negative, one can say with reasonable assurance that sugar was not produced by the kidney during the several-hour period of filling the bladder. Here one can extrapolate backwards with some safety. On the other hand, the usual electrocardiogram or electroencephalogram is a statistically insignificant sample of what has occurred over a period of several hours. Hence, I suggest that suitable physiological phenomena be recorded at the site of occurrence in such a way as to provide the physical freedom necessary for normal daily activity. The electrocardiocorder can be made into an electroencephalocorder to free a brain-test subject from his radio-receiver environment, and it should be possible to design suitable analyzers.

The Future

When I speak of "full freedom" through the elimination of wires, restricted locations, electronic baggage, and radio interference I mean freedom within the limits of electronic and mechanical performance. Thus, there will always be room for improvement of the equipment, but, basically, "full freedom" means freedom to make long, continuous records of physiological phenomena as close as possible to the geographic site of occurrence. Thus the future—and this development may not be remote, in view of the present increasing interest in medical electronics —will see human beings and other animals of many types "wired for research," with numerous little boxes piling up information about body function. Numerous physiological variables will be recorded in one over-all portable recording system and coded into one record for later study by more sophisticated analyzers than those described here.

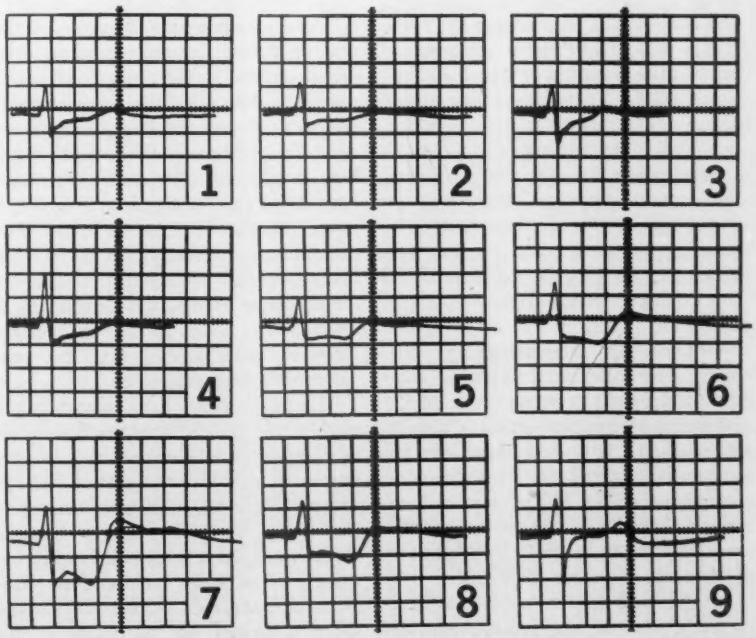


Fig. 9. Frames from a moving picture of an AVSEP pattern, showing an attack of angina pectoris in an individual doing forbidden heavy work.

Summary

I have proposed that orthodox electrocardiography be implemented, both for research and medical purposes, by the use of long-period, continuous recording of heart potentials with a portable, self-contained instrument—the electrocardiocorder together with semiautomatic methods for the rapid analysis of the resulting voluminous data. An electronic system to make this concept practical has been developed in our laboratory and typical results are described in this article.

References and Notes

1. J. A. Gengerelli and N. J. Holter, *Proc. Soc. Exptl. Biol. Med.* **46**, 532 (1941); **49**, 220 (1942).
2. J. A. Gengerelli, *ibid.* **51**, 189 (1942).
3. ———, *ibid.* **52**, 189 (1943); ——— and V. Kallejian, *J. Psychol.* **29**, 263 (1950); J. A. Gengerelli, *J. Comp. and Physiol. Psychol.* **44**, 535 (1951); ——— and J. W. Cullen, *ibid.* **47**, 204 (1954).
4. N. J. Holter and J. A. Gengerelli, *Rocky Mt. Med. J.* (Sept. 1949); Proc. AAAS, 117th Annual Meeting, Cleveland (1950); W. R. Glasscock and N. J. Holter, *Electronics* (Aug. 1952).
5. N. J. Holter, *Ann. N.Y. Acad. Sci.* **65**, 913 (1957).
6. J. A. Gengerelli, N. J. Holter, W. R. Glasscock, *J. Psychol.* **52**, 317 (1961).
7. H. F. MacInnis, *Can. Med. Assoc. J.* **70**, 574 (1954).
8. N. J. Holter, Progr. Rept., Public Health Service research grant No. H-2614(C2) (1959).
9. W. R. Glasscock has made major contributions to the mechanical and electronic design of these instruments. Electronics technician Frank Theobald has given valuable assistance in this study. This work was supported, in part, by Public Health Service grant No. H-2614. The names *Radioelectrocardiograph, Electrocardiocaster, Electrocardiocorder, AV-SEP,* and *Arrhythmiagraph* are Holter Research Foundation trademarks.
10. N. J. Holter and W. R. Glasscock, *Proc. Montana Acad. Sci.* **18(1958)**, 35 (1958).
11. R. F. Abarquez *et al.*, *Circulation* **22**, 1060 (1960); C. E. Pruett and J. N. Shellabarger, *Naval Research Revs.* (Feb. 1961); D. A. Rowley *et al.*, *Am. Heart J.* (Aug. 1961); J. S. Gilson and R. B. Griffing, *Am. J. Cardiol.* **8**, 212 (1961).
12. H. A. Lindberg *et al.*, *A.M.A. Arch. Intern. Med.* **106**, 628 (1960).
13. E. Corday, private communication.
14. J. S. Gilson, N. J. Holter, W. R. Glasscock, Proc. American Heart Association, 34th Annual Meeting, Miami Beach (1961).

Mass Spectrographic Analysis of Solids

High sensitivity for bulk and surface impurities is provided by a new analytical method.

N. B. Hannay

In the last few years there has been a great deal of interest in the application of mass spectroscopy to the analysis of solids. This interest has arisen because there clearly exists a need for an analytical instrument with a broad range of capabilities for analyzing very low concentrations of impurities in solids. High-purity materials are rapidly becoming of great technological importance in a number of different fields. For example, concentrations of impurities of 1 part in 10^9 are of great importance in semiconducting materials. The best comprehensive analytical instrument at present is generally considered to be the optical emission spectrograph. This instrument has its limitations, however; impurities at concentrations below 1 part per million cannot generally be detected, and the sensitivity for a considerable number of elements is poorer than this.

In the search for new analytical methods, one of the most promising is mass spectroscopy. Because of the diverse nature of the problems that are of interest in the analysis of solids, several different mass spectroscopic methods of analysis have been developed by workers in this field. Thus, high-sensitivity techniques (*1*) have been developed for the detection of specific impurities in certain cases. For example, the "isotope dilution" method, in conjunction with either a thermal ionization or an electron bombardment source, has been applied to certain kinds of solids analysis and has provided very high sensitivity.

The most useful mass spectroscopic method for general analysis makes use of the vacuum spark source. In this source a high radio-frequency voltage (50 to 150 kv) is applied between two closely spaced electrodes to form a spark; the voltage is pulsed at a repetition rate of some hundreds or thousands of cycles per second, so that the spark is broken and re-formed at this frequency. This method has only very recently been exploited to any appreciable degree. The reason for this undoubtedly lies in the instrumental difficulties associated with the use of the source, although its potential usefulness is great.

The spark source has several advantages for the analysis of solids. It is a source of great generality, in that it has no blind spots for any element and can be used with approximately the same degree of sensitivity for any element. It is quite free from the contamination problems that arise, for example, in connection with the electron bombardment source when a furnace is used to vaporize the solid into the source region. On the other hand, the spark source is erratic in its behavior, and the fluctuating ion current makes recording problems difficult. Ion currents from the spark source are not especially high. The spark source cannot be used with most existing, conventional instruments; a double-focusing instrument, which provides both direction and velocity focusing, is needed because of the large spread in initial energies of the ions. Since double-focusing instruments are relatively rare, the use of the spark source for analytical purposes has been extremely limited despite its potentialities. The very recent introduction of commercial instruments of this type is rapidly altering this situation, however.

Historical Background

The spark source was introduced into mass spectroscopy by A. J. Dempster in 1934 (*2*). At an early date Dempster realized the possibilities of the source for the analysis of solids, and the method was used during World War II by Dempster and his group for

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analytical purposes. One brief report of this work has been published (*3*), which points out some of the advantages of the method. Dempster's work showed that the sensitivity of the mass spectrographic method was at least as high as 1 part per million, and it clearly indicated the possible usefulness of the spark source for general analytical work, but it was not sufficiently broad to establish firmly the sensitivity limit or the wide scope of the method.

The next application of the method was that of Gorman, Jones, and Hipple (*4*). In this work, a Dempster double-focusing mass spectrograph was adapted for analytical purposes, the principal modification being the introduction of electrical recording. This was accomplished by measuring the ratio of the mass-analyzed ion current emerging from the exit slit to a monitoring current representative of the total current from the source. Difficulties due to the fluctuating nature of the spark source were thus circumvented, and electrical detection was made not only feasible but quantitative. These authors applied the method to the analysis of a series of stainless steel samples and determined chromium and nickel concentrations ranging from 0.25 to 25 percent with a high degree of accuracy and precision. The construction of an instrument designed for analytical purposes was described by Shaw and Rall (*5*), but no results were reported.

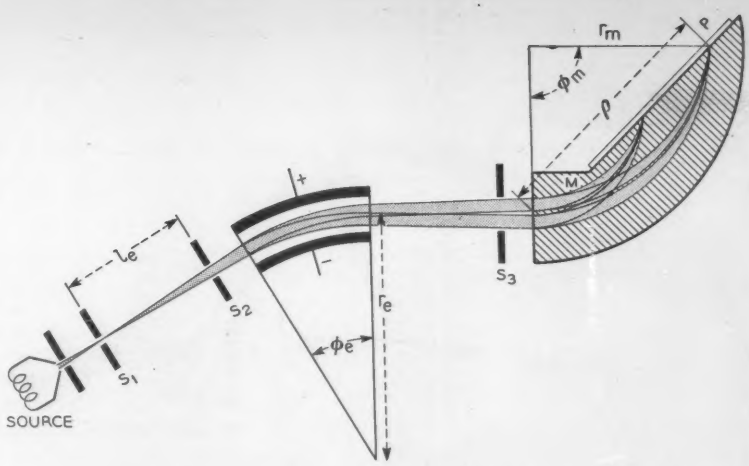

Fig. 1. Double focusing in a Mattauch-type mass spectrograph.

Instrumentation

A mass spectrograph for the analysis of solids was described in 1954 (*6*), and analytical results were also given (*7*). The commercial instruments that have more recently become available are similar in general design. In each case double-focusing mass spectrographs of the Mattauch type have been used. For photographic recording the Mattauch geometry offers great advantages over other double-focusing designs because of its property of being simultaneously double-focusing for all masses. This permits simultaneous photographic recording of a large range of masses. Figure 1 shows schematically how the focusing works; the electrostatic analyzer selects for transmission ions of a certain energy range, with no mass separation, and focuses the ions of a given energy at infinity. Two such beams of parallel ions are shown in Fig. 1, representing two typical initial ion energies, with two different masses present. The magnetic field refocuses the parallel beam and compensates for the divergence of the beam resulting from the spread in initial energies, providing mass analysis at the same time.

The large voltage in the spark results in a wide range in initial energies. A slit between the electric and magnetic fields determines the fraction of these which is used. Usually ions with a spread in initial energy of well over 100 electron volts are admitted. It turns out that ions with a spread in initial energy of more than 5000 electron volts originate from the source.

Figure 2 shows schematically one such instrument (*6*). At the left is the source region, showing two electrodes made from the material being analyzed, together with the mechanism for adjusting their position. The removable source plate is shown in Fig. 3. The electrodes, which are about 1 millimeter in diameter and 5 to 10 millimeters long, are held in stainless steel pin chucks. The operation of the spark is observed through the three windows provided in the all-metal system. After acceleration of the ions into the slit system, the ions are deflected electrostatically through an angle of 31°50′ into the cylindrical electrostatic analyzer. Upon emerging from this analyzer, the ions are deflected through an angle of 90° in the magnetic analyzer. The final focusing of the ions occurs at the exit plane of the magnetic analyzer, the ions emerging at an angle of 45° to this plane.

The ions may be recorded either photographically or electrically, the former method being generally preferred. For electrical recording a metal plate carrying an exit slit is inserted in place of a photographic plate, and the ion beam emerging through this exit slit is collected in a Faraday cage. With photographic recording, it is desirable to put more than one exposure on a single plate, and a rack and pinion mechanism is used to move the plate across the exit of the magnetic analyzer, thereby allowing several exposures to be made on one plate without breaking the vacuum.

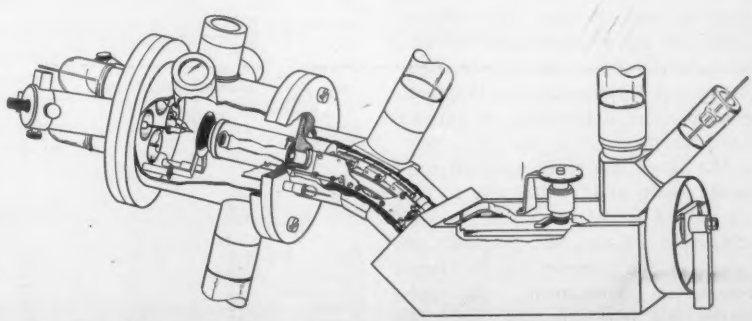

Fig. 2. Schematic drawing of a mass spectrograph for the analysis of solids.

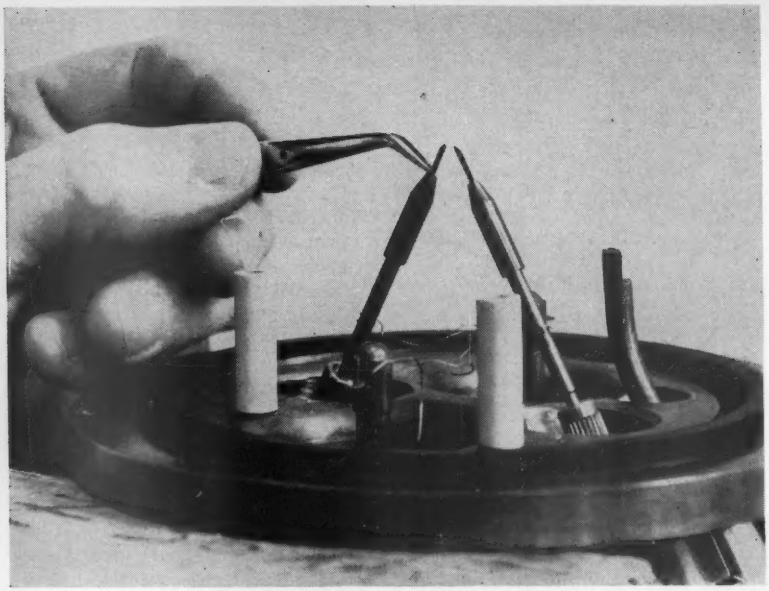

Fig. 3. Source plate, showing electrode system.

The advantages of photographic recording are that all masses are simultaneously recorded and that the sensitivity is very high.

Two separate vacuum systems are provided, one for the source chamber and one for the analyzer region. The only connection between these is through the entrance slit, which may be of the order of 0.002 inch wide, so that gases generated in the source during the operation of the spark do not give as large a pressure rise in the analyzer region as in the source region. Cut-offs are provided on the vacuum lines to facilitate the changing of samples; the procedure requires the venting only of the instrument itself, while the pumps and traps are kept in operation. A preferable arrangement is to provide a cut-off valve between the source and the analyzer regions, and this is done in the commercial instruments. The source plate can be removed for changing samples, and a lock on the magnetic analyzer gives access to the photographic plate region. A chamber for pre-pumping the photographic plates is provided on commercial instruments.

The spark source is operated on a pulsed basis, as it is desirable to keep the voltage in the spark high to avoid selectivity effects for different elements in the sample. In the newer commercial instruments the pulse length and repetition rate are easily varied, and this provides a convenient means of selecting a wide range of exposures. A series of graded exposures for a given sample is recorded on a single photographic plate. By comparing impurity and major-component mass spectral lines that fall within the measurable range of optical densities, impurity concentrations covering several orders of magnitude can be determined on a semiquantitative basis.

Typical plates are shown in Fig. 4. The line widths and positions increase with the square root of the mass. About a 15-to-1 mass range can be covered in a single exposure, and the range may be selected by an appropriate choice of the magnetic field; a convenient range has been found to be from mass 8 to mass 120. In Fig. 4 are reproductions of mass spectra representing, respectively, a high-purity lead sample, a high-purity germanium sample containing added antimony (6 parts per million), an antimony sample containing arsenic (100 parts per million), a steatite sample, a copper sample with one monolayer of gold deposited on its surface, and a germanium sample with one monolayer of indium deposited on the surface. In the case of the last two exposures the impurity lines appear only on the first exposure and disappear in subsequent exposures. In all other cases all of the lines remain constant during successive exposures.

Table 1. Determination of concentrations of impurities in aluminum (in parts per million).

Element	Known composition	Av. for five analyses	Standard deviation
	Sample AA1		
Silicon	476	480	110
Titanium	12	7	1
Manganese	10	8	2
Nickel	5	8	2
Copper	11	11	3
Zinc	6	4	1
	Sample AA3		
Silicon	1975	1370	120
Titanium	34	36	7
Manganese	110	93	7
Nickel	46	49	7
Copper	83	90	20
Zinc	33	30	4

Bulk Impurities

In order to discuss the analytical uses of the instrument, let us first consider what kinds of questions we may reasonably hope to answer with the method. One kind of problem in the determination of bulk impurities is that of obtaining purely qualitative information as to the impurities that may be present in the solid sample. When this kind of information is obtained, one usually finds that it is also desirable to make at least a rough estimate of the concentration. It is frequently of interest to obtain fairly accurate data in comparing two samples—that is, to determine with considerable precision what the relative amounts of an impurity may be in two samples. Finally, there is the problem of determining with a high degree of accuracy the exact concentration of an impurity in a solid sample. Except for the last of these problems, the photographic plate is preferable in many respects to electrical detection. For a general survey of an unknown sample, where one does not know what impurities to expect, the fact that the plate records simultaneously all masses is an enormous advantage. For comparison of samples, and for rough estimation of the impurity concentration, the photographic plate can give results accurate to within a factor of 2 or 3, and this is usually adequate.

Where a high degree of accuracy is needed, one must resort to electrical detection. The nature of the problem of sensitivity in electrical detection and recording may be seen from the fact that the total ion current emerging from the magnetic analyzer is approximately 10^{-10} ampere. An impurity at a concentration of 1×10^{-7}, therefore, corresponds to a current of the order of 10^{-17} amperes. This is beyond the

range of direct-current amplifiers and vibrating-reed electrometers, although it is within the capabilities of electron multipliers. The still lower impurity concentration (10^{-9}) detectable photographically is beyond the range where even electron multipliers can be used conveniently. The photographic plate is an extremely sensitive detector of positive ions. A current of 10^{-17} ampere can be easily detected on a photographic plate if it strikes an area of approximately 1 square millimeter over a period of 2 minutes. Thus, an easily detectable image is seen on the photographic plate when it is struck by 10^4 ions per square millimeter at an energy of 20 kev. When the ions are focused on a smaller area, still lower currents may be detected. This sensitivity for ion detection is considerably higher than has been previously reported for positive ions.

If time is used as a measure of exposure, inaccuracies appear because the fluctuating nature of the spark makes it difficult to maintain a constant ion current through the instrument while the spark is running. The fluctuating nature of the spark has no effect on the accuracy of the results, however, when the monitor electrode, between the electric and magnetic fields, is used to measure the total exposure. This measurement is conveniently made by simply measuring the total charge collected by this electrode during the run. The exposure is chosen through suitable selection of the spark operation time and pulse conditions, as mentioned earlier.

The photographic line density is proportional to the exposure over a range of approximately two orders of magnitude when Ilford Q-2 plates are used. A comparison of line density and total exposure provides a number which is representative of the mass spectrographic determination of the impurity concentration. Concentrations determined in this way for a series of standard samples of boron in silicon are shown as a function of the known concentration of boron in Fig.

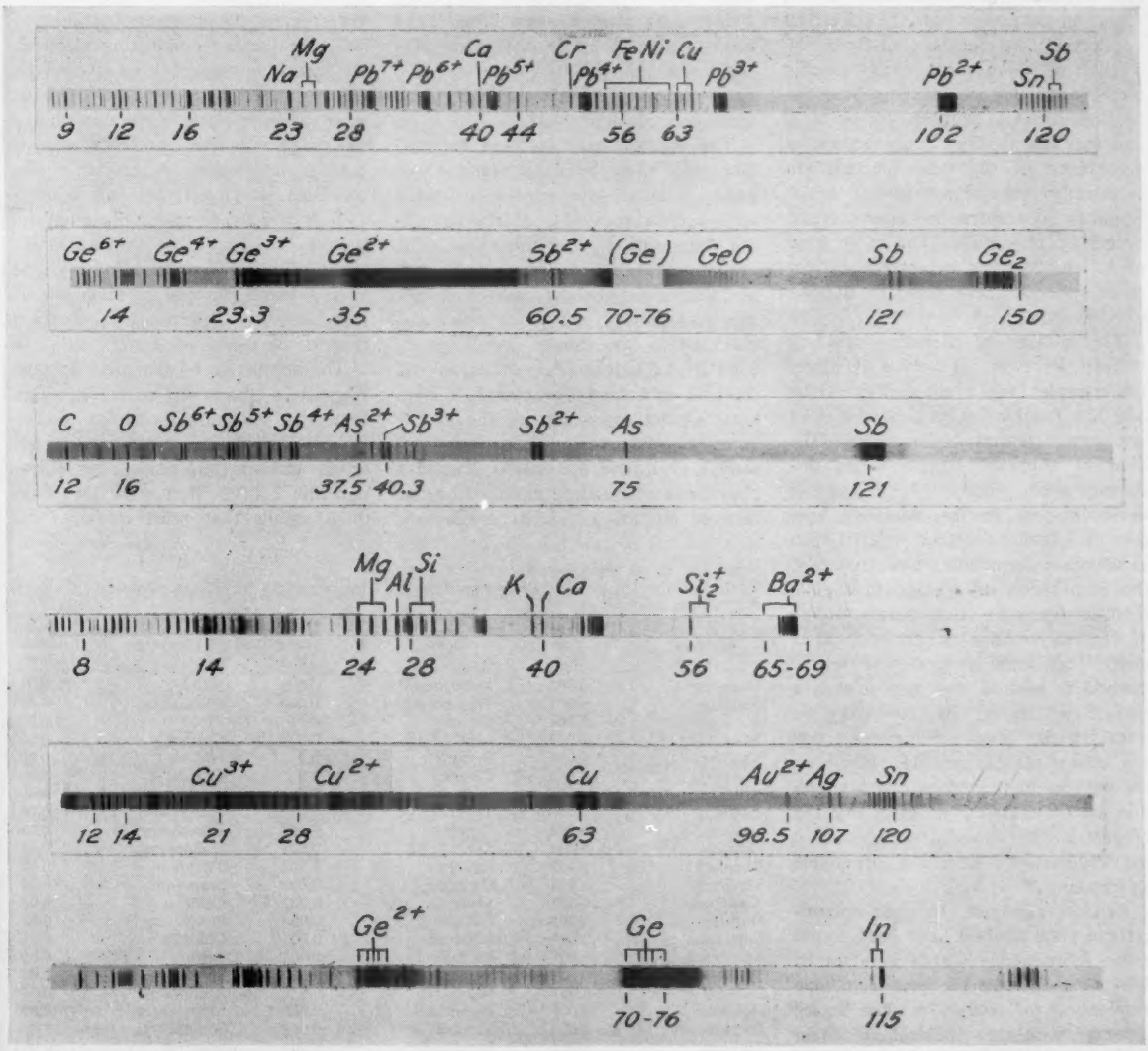

Fig. 4. Typical mass spectra. (From top) "High-purity" lead; germanium with added antimony (6 parts per million); antimony with arsenic (100 parts per million); steatite, with high-purity silicon reference electrodes; copper, with one monolayer of gold deposited on its surface; germanium with one monolayer of indium on its surface.

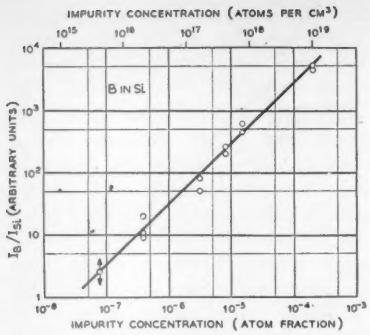

Fig. 5. Mass spectrographic determination of standard samples of boron in silicon.

5. The concentrations for these standard samples were accurately known from measurements of the electrical conductivity. It may be seen from Fig. 5 that with the mass spectrographic method the boron concentration can be determined to within a factor of 2, and that the impurity concentration as determined by the mass spectrograph is directly proportional to the actual impurity concentration over several orders of magnitude. The same kind of information has been obtained for other systems where standard samples were available.

The problem of preparing standard samples is severe, as only a relatively few samples are available for which one has reliable information for very low concentrations of impurities. The kind of standard sample series discussed above, boron in silicon, is available only in the relatively rare case of a semiconducting material such as silicon or germanium. Unfortunately, the preparation of a standard sample involves far more than merely adding a weighed amount of impurity to a melt. The most general and useful method is to add this impurity as a radioactive tracer; by counting the tracer in the given solid sample, one can obtain reliable samples. However, the number of impurities and matrices that are of interest is so great that the preparation of standard samples, even with radioactive tracers, is a formidable undertaking.

Results obtained by the photographic plate method have been found to be reproducible within a factor of 2 in all cases we have examined. One may expect, of course, an even higher accuracy with the electrical recording method. In our own work we have found that a higher accuracy is only rarely required, and that the photographic plate method, when used for comparing samples and for semiquantitative determinations, has been entirely satisfactory. In making comparisons between samples it has been found helpful to mount two pairs of sample electrodes in the source at the same time and to make two groups of exposures on the photographic plate, one group being used to record each of the unknown samples. By this means variations attributable to the photographic plate, to vacuum conditions, and so on are minimized.

The reproducibility of the method is well illustrated by the analytical results obtained for impurities in two samples of aluminum by Craig, Errock, and Waldron (*8*), shown in Table 1. It may be seen from these results that, for all the impurities examined, the mass spectrographic analysis was in good agreement with the independent analysis.

The method may be used for any inorganic solid. Solids containing organic materials are usually excluded to avoid the possibility of contaminating the inside of the instrument with material that would appear thereafter as background. In the case of metals the material is cut into rods and mounted in pin chucks, as shown in Fig. 3. Less than 0.1 milligram of material is actually consumed in several minutes' operation of the spark. Nonconducting materials such as ceramics or quartz are sawed into thin plates, one of which is mounted on the face of one of a pair of conducting

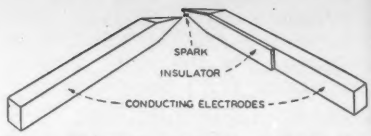

Fig. 6. Electrode system for analysis of a nonconducting solid.

electrodes such as high-purity silicon, as shown in Fig. 6. When the radiofrequency voltage appears between this pair of electrodes, the voltage is high enough across the gap so that, even with the insulator present, a spark is formed. The operation of the spark in this case proceeds very much as though the insulator were not present. One obtains, of course, not only the mass spectrum of the insulator but also that of the reference conducting electrode. By recording the spectrum of the conducting electrodes alone on the same photographic plate, their contribution to the composite spectrum can be readily determined. A similar system has been used by James and Williams (*9*). It is possible to handle powdered samples by packing them into metal tubes of small diameter. In this case, also, a blank run can be made on the metal tube to determine its contribution to the mass spectrum.

The sensitivity of the mass spectrographic method is extremely high. Estimated detection limits for a number of elements in a representative material, gallium phosphide, are shown in Table 2 (*10*). It may be seen from these results that most elements can

Table 2. Estimated concentration detection limits for impurities in gallium phosphide (in parts per million, atomic).

Element	Detection limit	Element	Detection limit	Element	Detection limit
Uranium	0.001	Neodymium	0.008	Arsenic	0.01
Thorium	0.001	Praseodymium	0.001	Germanium	0.03
Bismuth	0.001	Cerium	0.01	Zinc	0.006
Lead	0.002	Lanthanum	0.003	Copper	0.005
Thallium	0.005	Barium	0.2	Nickel	0.005
Mercury	0.003	Cessium	0.01	Cobalt	0.003
Gold	0.001	Iodine	0.01	Iron	0.003
Platinum	0.003	Tellurium	0.03	Manganese	0.003
Iridium	0.002	Antimony	0.002	Chromium	0.01
Osmium	0.002	Tin	0.003	Vanadium	0.01
Rhenium	0.002	Indium	0.001	Titanium	0.01
Tungsten	0.003	Cadmium	0.003	Scandium	0.01
Tantalum	0.001	Silver	0.002	Calcium	0.01
Hafnium	0.003	Palladium	0.004	Potassium	0.01
Lutecium	0.001	Rhodium	0.001	Chlorine	0.01
Ytterbium	0.003	Ruthenium	0.005	Sulfur	0.03
Thulium	0.001	Molybdenum	0.004	Silicon	0.03
Erbium	0.003	Niobium	0.3	Aluminum	0.003
Holmium	0.001	Zirconium	0.006	Magnesium	0.003
Dysprosium	0.004	Yttrium	0.001	Sodium	3
Terbium	0.001	Strontium	0.001	Fluorine	0.003
Gadolinium	0.004	Rubidium	0.05	Boron	0.001
Europium	0.002	Bromine	0.02	Beryllium	0.001
Samarium	0.004	Selenium	0.02	Lithium	0.003

be detected at concentrations in the 10^{-8} to 10^{-9} (atom-fraction) range. Similar sensitivities have been found for another instrument (*11*). A summary of detection limits in four different types of materials, as given by Craig *et al.* (see *8*), is shown in Table 3.

Table 3. A summary of detection limits for impurities in four different types of materials.

Detection range [concentration (atom-fraction)]	Number of elements detected in			
	Aluminum	Graphite	Gallium arsenide	Silicon
$\leq 10^{-9}$	16	41	4	9
2×10^{-9}–10^{-8}	38	27	50	45
2×10^{-8}–10^{-7}	12	3	14	14
2×10^{-7}–10^{-6}	5	0	3	5
$> 10^{-6}$	0	0	0	0

Limitations on the sensitivity of the instrument fall into two categories. There are always present a small number of background lines due to residual gas in the instrument, and these lines may appear at several places in the low mass region. Improved vacuum conditions, of course, result in a reduction in the number of these lines. Because some of them are always present, however, it is not possible to make a determination for carbon, nitrogen, oxygen, and hydrogen at very low concentrations. The second limitation, and a more important one, results from a diffuse background that appears on the photographic plate as a result of scattering of the ions by residual gas. This scattering is frequently accompanied by a change of charge or mass of the ion. According to what change of charge or mass occurs, and where it occurs, one can easily calculate the region of the photographic plate over which the diffuse background should appear. This effect can be greatly reduced by improving the vacuum conditions. One effective way to do this is to bake the instrument.

Surface Impurities

Although the instrument was not primarily constructed for the determination of surface contaminants, this has developed into an application of considerable importance. One can determine surface impurities because the spark initially samples the surface, then, as the operation proceeds, chews into the interior of the material and attacks little in the way of new surface area. Thus, the spectrum that one obtains when the spark is first operated includes not only bulk impurities but surface contaminants, while the spectra obtained subsequently reflect bulk impurities almost exclusively. As indicated earlier, the sensitivity of the instrument in which the electrode arrangement shown in Fig. 3 was used was such that 0.1 monolayer of a surface impurity could be detected. An obvious way to increase the sensitivity for surface contaminants is to change the geometry of the electrode system so that a larger area of surface can be scanned. By using a point against a wedged-shaped surface, approximately 0.1 square centimeter of area can be conveniently scanned, and it has been determined that a surface impurity of less than 0.01 monolayer can be easily detected. In Fig. 4, mass spectra are shown for a monolayer of gold on copper and for a monolayer of indium on a germanium sample. The indium-113 line is clearly visible on the original plate, and this corresponds to a surface coverage of 0.04 layer (corresponding to the 4-percent isotopic abundance of indium-113). Surface impurities on insulating materials, such as ceramics, have also been successfully investigated in this way.

Conclusions

The mass spectrograph is not considered to be an instrument that will replace the emission spectrograph, because it is inherently more complicated. On the other hand, it is an extremely useful instrument and can handle problems of a semiquantitative nature that the emission spectrograph and other methods cannot handle, and thus it complements these methods. As has been shown, these problems include both the determination of low concentrations of bulk impurities and the determination of surface impurities which cannot be handled conveniently by any other known method. Bulk impurities down to a level of 10^{-9} (atom-fraction) and surface impurities of less than 0.01 monolayer can be detected (*12*).

References and Notes

1. For references to the literature see G. P. Barnard, *Modern Mass Spectrometry* (Institute of Physics, London, 1953) and H. E. Duckworth, *Mass Spectroscopy* (Cambridge Univ. Press, Cambridge, England, 1958).
2. A. J. Dempster, *Proc. Am. Phil. Soc.* **75**, 755 (1935).
3. ———, "The mass spectograph in chemical analysis," *U.S. Atomic Energy Comm. Paper No. MDDC-370* (1946).
4. J. G. Gorman, E. J. Jones, J. A. Hipple, *Anal. Chem.* **23**, 438 (1951); J. A. Hipple and J. G. Gorman, "Mass spectrometric analysis of solids with the high-frequency spark," *ASTM Spec. Tech. Publ. No. 149* (1943).
5. A. E. Shaw and W. Rall, *Rev. Sci. Instr.* **18**, 278 (1947).
6. N. B. Hannay, *ibid.* **25**, 644 (1954).
7. ——— and A. J. Ahearn, *Anal. Chem.* **26**, 1056 (1954).
8. R. D. Craig, G. A. Errock, J. D. Waldron, in *Advances in Mass Spectrometry* (Pergamon, London, 1959).
9. J. A. James and J. L. Williams, *ibid.*
10. R. Brown, R. D. Craig, J. A. James, C. M. Wilson, Proceedings, Conference on Ultrapurification of Semiconductor Materials, Boston, Apr. 1961.
11. G. D. Perkins, C. F. Robinson, R. K. Willardson, private communication; C. F. Robinson, G. D. Perkins, N. W. Bell, Proceedings 5th International Instruments and Measurements Conference, Stockholm, Sept. 1960.

12. A number of the techniques described were developed by A. J. Ahearn, to whom I am indebted also for comments on the manuscript.

Science and the News

The Consortium Proposal: Private Industry Offers a Plan for Developing Satellite Communications

A consortium of American corporations handling international telephone and telegraph traffic submitted a proposal last week for organizing a nonprofit corporation to own the United States interest in a satellite communications system. The corporation would be financed, initially, by a $50 million investment by American Telephone and Telegraph, and by much smaller contributions from other members of the consortium. The corporation would be governed by a board made up of two members from each company contributing $500,000 or more, three members appointed by the government, and one member to represent the interests of companies which would like to share in the use of the satellites but which are not in a position to invest a substantial amount of money.

The central idea for this type of directorship was to allay concern that the corporation would be dominated by A.T.&T., which would be, by far, both the greatest investor and the greatest user of the satellite network.

Western Union, though, submitted a minority report arguing that even with A.T.&T. limited to two members on the board, it would still dominate the corporation through its investment and volume of business, which would amount to something like twice that of all the other companies involved. Western Union, principally on this ground, asked that participation be opened to anyone who wished to invest, and not limited to companies in the international communications business. This idea commands wide support among manufacturers of communications equipment and other firms which have a stake in the policies of a satellite corporation.

The question of just how the satellite venture will be organized remains very much up in the air, and only in part because of the domestic problem which caused Western Union to submit a minority report. This domestic problem centers on the question of how to organize the privately owned corporation in a way that will satisfy the antitrust division of the Justice Department and smaller companies that A.T.&T. will not dominate the venture. Assuming this can be settled, there remains the problem of how to organize *any* satellite venture, other than one owned by the government, in a way that would assure that the very substantial national interest in the venture, and the manner and speed with which it is developed, will be properly safeguarded.

Official Policy

The U.S. policy, announced at the beginning of the summer when the consortium was invited to submit a proposal, is that private ownership is preferred, provided that both the domestic (antitrust) and the international problems can be worked out. Among the international conditions that had to be met were that the system should offer world-wide service, rather than concentrate on the more profitable high-traffic transatlantic communications, and that participation in the ownership and use of the system should be available to any country that wishes to participate. These conditions imply that the corporation, particularly in providing service for the less-developed countries, would have to develop policies quite different from those which would be dictated if profit-and-loss considerations were the sole concern of the management.

Last week's consortium proposal increased the likelihood of a privately owned system, if only in the negative sense that the proposal accepted all the conditions laid down by government. There had been a good deal of talk, some of it coming from the companies involved in the consortium, that the conditions that the government had laid down were such as to make it impossible for the satellite system to be developed under private ownership. But the proposal offered by the consortium last week accepted all of the government's conditions without reservation, and so suggested that the companies involved felt they could handle the special burdens that the international problem would place on the enterprise.

What would happen under the proposal would be that the satellite venture itself would be nonprofit, but with the companies involved including their investment in the satellites as part of their expenses in justifying their rates to the Federal Communications Commission. The companies would thus receive a return on their investment, including the extra expense involved in providing world-wide service. Presumably, if these additional expenses should prove great enough to make the rates excessive, the satellite corporation would ask the government for a subsidy to cover all or part of the additional expenses. But the companies did not suggest that they would need a subsidy, and if the optimistic forecasts that are generally made about the costs of satellite communications prove correct, the system might well be able to operate privately, without a subsidy, and still provide rates as cheap as, or cheaper than, current transatlantic cable and wireless rates.

Yet the problems involved remain extremely complex, and the proposal submitted last week, while increasing the chance of private ownership, does not assure such ownership.

Though the consortium accepted, in principle, the government's conditions, the question of how well the arrangement would serve, in practice, what the Administration sees as a great national interest in the way the operation is run is impossible to answer, and on the domestic problem, as the Western Union minority report suggested, there is, as yet, no general acceptance even within private industry of any particular arrangement for private ownership.

A good many basic questions about the technical nature of the system will remain unanswered until at least late next year, when some data will become available on the effectiveness of several kinds of trial satellites that will be placed in orbit. At the moment, even the most basic technical question of whether the system should use a small number of satellites orbiting at high

altitudes or a fairly large number at moderate altitudes is still unresolved, although this decision will determine the kind of ground stations that will be necessary, and to a considerable extent, the ease with which the system can be engineered to provide worldwide coverage, and television as well as radio communications.

Without this basic technical information, and a good deal of nontechnical information as well, no one can be sure just how well the consortium, with the best of intentions, might be able to live up to the government-imposed conditions they have offered to accept, or how much of a conflict might develop between the government's and the consortium's views on specific policies required to carry out the conditions in a specific situation. The consortium and the government have agreed on general principles, but agreement on general principles is rarely much assurance that there will be agreement on how to put the principles into practice when concrete situations have to be faced, and very little assurance at all in this matter of satellite communications since neither the government nor the consortium can have more than a general idea about the nature of the concrete situations that will have to be faced.

At the moment, the consortium proposal is, in any case, only a skeleton, which will take on a definite shape in the course of further negotiations, assuming, of course, that the government finds the proposal basically acceptable. But the greatest question in the negotiations will be over the extent of control the government will retain in order to assure that the conditions that have been accepted will be satisfactorily carried out.

On this issue, the consortium proposal grants the government a voice on the board of directors larger than any individual participant, but smaller than any two of the private companies involved, and of course much smaller than all the private companies together. The government did not specifically ask for even this much of a formal voice in the management, but as the consortium recognized, the peculiar nature of the venture implied that the government would have to have a voice in its management.

So far, the Administration has not spelled out the degree of control over the venture it feels it must have. The private companies have not spelled out the degree of control they would be willing to live with. The issue of how great a voice the government should have, and the mechanisms for making its voice heard, remains not only unresolved, but almost untouched.

The Test Ban Again

Khrushchev's announcement that the current Soviet test series will be climaxed on 31 October with a 50 megaton explosion raised the question of how the U.S. will handle its response to a likely Soviet announcement, after the conclusion of the series, that it is now prepared to resume the 3-year-old moratorium it broke at the end of August. The response is almost certain to be a negative, and hence an unpopular one to the world at large.

Both the Soviet Union and the U.S. have taken firm positions on the question of underground testing. Last week, Arthur Dean, our chief negotiator at Geneva, and now representing us at the U.N. test-ban debate, said he still believed the Russians would come to terms on an enforceable ban, since it is, he said, in their own interest to do so. But the Russians themselves have been saying nothing to encourage this view. Instead they have been talking, publicly, of how it would be easy to reach agreement on the test ban question *after* agreement has been reached on general and complete disarmament, and, privately, that they realize that the controls necessary for an enforceable ban are just too great for them to accept to get an agreement that involves no real disarmament.

As for the United States, the course of the American handling of the test ban issue since last spring, when the hardening of the Russian attitude first became apparent, makes it most unlikely that the Administration would agree to another unpoliced moratorium on underground tests. The assumption in the Administration all along had been that the United States would, sooner or later, have to break the moratorium, in view of the apparent lack of any Soviet interest in a controlled ban so long as they could have all the advantages of a ban without having to accept any controls, simply by dragging out the talks indefinitely.

There has been some criticism in this country, and more in friendly nations abroad, that we did not put off the resumption of underground tests long enough following the Soviet resumption of atmospheric tests. The reasoning, in most cases, was not based on a belief that the U.S. could abstain from testing indefinitely in the face of the Soviet resumption, or even in the face of an obvious lack of interest by the Russians in accepting controls for underground tests. The arguments, in the main, have been merely that we could have produced a better propaganda effect by holding off for a while longer. The difficulty with this is that the Administration, feeling it would have to resume underground testing in any case, had no desire to let the Russians complete their current series of atmospheric tests, announce they were ready to resume the moratorium, and put the U.S. in the position of having to break the ban after the Russians had announced they were resuming it. As long as testing had to be resumed, the time to do it was during the Russian series, whose duration was unknown. Thus the resumption could not be delayed very long without risking a major propaganda loss in return for a marginal propaganda gain.

If that the Rusians do soon announce they are ready to resume the ban, one of several propaganda problems the U.S. will face is that there is a tendency among people whose sympathy we would like to win to assume, simultaneously, (i) that underground testing is just as much an acceleration of the arms race as atmospheric testing and (ii) that the United States can afford to accept a moratorium on underground testing because the Russians could not make sufficient weapons progress through underground testing to upset the balance of power even if they were to conduct secret tests in violation of an unpoliced moratorium. This allows some of our friends, to argue that a ban limited to atmospheric testing is not really much more desirable than no ban at all, that U.S. testing underground, therefore, is as bad as Soviet testing in the atmosphere, and at the same time that the United States has no good reason to be concerned that the Russians could gain any real advantage from secret underground tests. These contradictory views are often bolstered by an assumption that we could really detect underground tests anyway. This assumption, presumably, is based on our failure to point to any secret Russian tests we have failed to detect in order to prove we couldn't detect them.—H.M.

Food for Peace: Ten Nations To Use Surplus To Aid Development

The Administration this week could point to some small but significant achievements in its efforts to change American farm surplus from a domestic burden to a foreign policy asset.

The change is not coming easily, for the goal of disposing of surplus has been dominant in American food programs since the current basic program was established in 1954. Nevertheless, the principal innovation of the new Administration in regard to foreign use of foods is now taking on considerable significance in the over-all program. This is the use of food for encouraging the developing nations to undertake economic development projects that require large-scale manpower and relatively little material and equipment.

Under programs now in effect in ten countries, food is being used in partial payment for labor on projects such as land clearing, reforestation, irrigation, road building, and school construction. In all cases, the workers receive cash payments in addition to food.

The 500,000 tons of food now committed to the program is a relatively modest portion of the foods that are available for shipment abroad, but it represents the amount that Food for Peace officials feel can be profitably absorbed for the time being. Funds carried over from previous years, along with the vast annual increments in available foods, provide the program with virtually unlimited resources, they point out. What is limited, however, is the ability of recipient countries to organize activities in which this abundance of food can be employed to develop resources that will in turn help them to stand on their own feet.

In a memorandum directing American missions abroad to seek to stimulate interest in this program, the International Cooperation Administration pointed out that "food should be offered only for projects which will enhance social and economic development and which are technically sound." Such projects, it has been found, are not easily arranged, and in this area, as in many others, the Administration is finding that the recognition of a problem and the desire to do something about it often still leave a satisfactory solution a long way off.

The impetus to use food for economic development came from the fact that many of the developing nations lack the capital to undertake simple projects that could play an important role in their economic development. Not surprisingly, it is apparent, they also lack the supervisory personnel and organization needed to take advantage of this program. The program's growth will be more related to developing nations' ability to absorb this assistance than to the willingness of the United States to provide it.

While the economic development program is being pushed hard by Food for Peace, the programs that are based on providing food simply to alleviate hunger are sending more tonnage abroad this year than in any previous year. Efforts are also being made to use some of this food to assist farmers while they are clearing new acreage or developing breeding stock. There are also school lunch programs that are designed to provide better nutrition for children, and also, to lure them to school.

In terms of tonnage, these efforts to promote development with food are small, but they reflect a determination to make imaginative use of our farm abundance.

Mental Retardation: The President's Concern Will Broaden Research

The sorrowful implications of mental retardation are in the personal experience of President Kennedy, whose sister Rosemary has long been institutionalized. Last week, at a news conference dominated by the international crisis, Kennedy devoted several minutes to drawing the nation's attention to the imbalance between the problem of mental retardation and efforts to cope with it. From the forum that he chose and the feeling that he put into his words, it is evident that Kennedy was not employing presidential hyperbole when he stated that the subject "is a matter of the greatest possible interest to me."

In his press conference announcement and in a longer statement issued by the White House, Kennedy pointed out that mental retardation at present afflicts 5 million Americans and that by 1970 an additional 1 million will be added to this group. These figures, he explained, far outweigh the number of persons suffering from many diseases for which great public concern has been aroused. For example, the President noted, mental retardation affects 10 times as many persons as diabetes, 20 times as many as tuberculosis, 25 times as many as muscular dystrophy, and 600 times as many as infantile paralysis. Nevertheless, expenditures for research have remained relatively modest, and, of more immediate concern, facilities for the care of mentally retarded persons are overburdened. The state institutions, he continued, average 367 patients above their rated capacities and have waiting lists averaging 340. For the 160,000 patients in the public institutions, there are only 500 full-time physicians.

To develop an expanded program of research into all phases of mental retardation, the President said, he would seek recommendations from a panel of outstanding persons in a variety of fields. The 24-member group, which was announced on Monday, is headed by Leonard Mayo, executive director of the Association for the Aid of Crippled Children, of New York. It is expected to present its recommendations to the President before the end of next year. In the meantime, the President would seek to double the $10.5 million that the National Institutes of Health spent in this field last year.

Since Congress has no tendency to argue about money for medical research, the President's concern is certain to be reflected in a greatly expanded program in the near future.

Soviet Defections: Conclusions of Broad Discontent Unwarranted

The defection of two Soviet scientists during the past 3 months has stimulated speculation in the press about the state of morale among Soviet scientists. Western scientists who are acquainted with their Soviet counterparts caution, however, that there are no grounds for doubting that the vast majority of Soviet scientists are well satisfied with their regime. These observers add that the defections are no more significant than the few cases involving Westerners seeking refuge in the Soviet Union.

The latest defection involved a 35-year-old biochemist, Alexei Golub, who received asylum in the Netherlands last week. Golub said he sought refuge because his superiors had interfered with his researches into the removal of strontium-90 from the human body. Last August, Mikhail A. Klotchko, a Soviet chemist who holds the Order of Lenin and the Stalin Prize, took refuge in Canada, also protesting against what he described as interference with his work.

Persons familiar with the Soviet scientific community point out that while Western scientists no doubt would find many aspects of Soviet life constricting, Soviet scientists appear to be quite content. Outside of the biological sciences, which have been severely affected by the dominance of Lysenko, there is little evidence that ideology has curbed scientific inquiry. The work of Soviet scientists not only is well supported by the government, but scientists also occupy an elevated position in Soviet society and are rewarded with superior pay scales, living conditions, and prestige.

What is perhaps most revealing on the question of scientific discontent is that defections among Soviet scientists are a rarity, though they are among the most widely traveled of their countrymen. Rigorous screening may, of course, be a factor, but it appears that the comfort that the West might derive from discontent in Soviet scientific ranks has led some persons to arrive at the conclusion that such discontent exists.

Area Redevelopment: Officials Defend Cautious Start

The recently established Area Redevelopment Administration finds itself somewhat haunted by the overly enthusiastic claims made by many of its backers in the course of winning Congressional approval.

The redevelopment program, which was one of the Administration's first major victories in Congress, is intended to bring new permanent jobs to economically depressed areas by helping to finance industrial development and public works needed to support industry.

While backers argued that the relatively small sum of $394 million would go a long way toward stimulating economic development in areas bypassed by prosperity, its opponents contended that the depressed areas could not be revived by spot applications of federal money. A third view was that the program was sound but needed vastly more money, but this was not pushed for fear of arousing antispending opposition.

The program, which has been operating 5 months, has not progressed much beyond the stage of processing applications, and has drawn from Commerce Secretary Hodges the observation that it is moving too slowly.

Redevelopment officials, however, caution that each project they undertake will be regarded as a precedent, and they insist that they prefer to move with care. Their principal problem, they insist, is that localities have been slow to come to them with soundly worked out projects, and under their Congressional mandate, they point out, they cannot go out to the country to drum up business.

What is plaguing them, they say, is that in getting the bill through Congress, backers of area redevelopment attributed to it therapeutic powers that will be a long time in coming, if they come at all.

Fallout Measurement: Soviets Opposed to a Role for the U.N.

The Soviet Union demonstrated again this week that its cooperation with the United Nations' scientific agencies is contingent upon their not undertaking activities which the Soviets regard as conflicting with their Cold War interests. In general, the programs of these agencies have been charted with this sensitivity in mind, and most U.N. scientific activities have flourished amid the problems that afflict the U.N.'s political organs. An exception is the International Atomic Energy Agency, where Cold War issues have arisen, and the Soviets have threatened to walk out.

The Soviet insistence upon what amounts to a scientific veto was emphasized Monday when a spokesman for the Communist bloc denounced a proposal to use the World Meteorological Organization to monitor radioactive fallout. The proposal, made by Canada and supported by 24 other nations, called for employing the existing weather stations in 102 nations and territories to gather and distribute fallout data. It was attacked by the communist spokesman as a propaganda move designed to further the Cold War objectives of the West, and it was made clear that if the WMO adopted the proposal, cooperation from the substantial portion of the world under communist rule would not be forthcoming.

As concern mounts over the radioactive fallout resulting from the Soviet Union's extensive series of atmospheric tests, the Communist bloc is not surprisingly reluctant to contribute data that document the hazard it has been creating.—D.S.G.

Announcements

A regional **counselor program in physics** has been established to promote local cooperation for better physics teaching in high schools. Specific projects of the program, supported by grants from the American Institute of Physics and the American Association of Physics Teachers, will include improving teacher training through cooperation with training institutions; strengthening the state and local syllabus in physics; assisting school systems in the proper selection of apparatus and laboratories; and promoting public awareness of the importance of physics teaching and the conditions under which it is done well.

Forty-one college professors and physicists in industry and government, appointed as counselors in 40 states and Puerto Rico, will interview state superintendents of education and state science supervisors and prepare reports of local developments concerning new curricula, enrollment changes, science projects, and science-teacher recruiting and training programs. (Regional Counselor Office, AIP, 335 E. 45 St., New York 17)

An **electronic information storage and retrieval system** will be developed for the National Library of Medicine by General Electric Company. The computer-based system, to be known as "Medlars," will be designed to process several hundred thousand pieces of bibliographic information annually, thus enabling the library "to broaden and accelerate its services to medical education, research, and practice." It is estimated that the development, installation, and testing of the system will take 2 years.

The National Academy of Sciences is compiling a register of American **scientists interested in overseas assignments**. Specialists in the biological and physical sciences and related fields who wish to be considered for such openings are required to complete and return a special form, available on request. (NAS, Committee on International Exchange of Persons, 2101 Constitution Ave., NW, Washington 25, D.C.)

The National Science Foundation has announced closing dates for receipt of the following proposals:

Design and development of **labora-**

tory equipment prototypes for school and college courses in mathematics, science and engineering; *15 November 1961*. Awards will be announced in March 1962. (NSF, Division of Scientific Personnel and Education, Washington 25, D.C.)

Basic **research in the life and social sciences**; *15 January* and *1 February 1962*, respectively. Proposals received prior to these dates will be disposed of approximately 4 months later. Proposals received after these dates will be reviewed following the summer closing dates (15 May and 1 May, respectively). (NSF, Washington 25)

Courses

A 4-day course on **surgical rehabilitation of arthritic deformities** will be held at the New York University Medical Center from 14 to 17 November. Although designed for orthopedic surgeons, sessions are also open to a limited number of experienced rheumatologists. Tuition: $85. (Associate Dean, N.Y.U. Postgraduate Medical School, 550 First Ave., New York 16)

Meeting Notes

A symposium on the application of **switching theory in space technology** will be held in Sunnyvale, California, from 27 February to 1 March 1962. The symposium, jointly sponsored by the U.S. Air Force and the Lockheed Missiles and Space Company, will consist of sessions on circuit logics, new switches and storage devices, and systems. (Rockwell Hollands, Newsbureau, Dept. 24-03, Bldg. 101, Lockheed Missiles & Space Co., Sunnyvale, Calif.)

A 3-day symposium on the basic problems in **neoplastic disease** will be held at Columbia University from 12 to 14 March 1962. The symposium will cover nucleic acid structure and synthesis; viral and genetic studies; protein synthesis; and antibody structure and function. Also included will be sessions on the clinical aspects of the biochemistry, pathological-physiology, morphology, and therapy of cancer. (Institute for Cancer Research, Columbia University College of Physicians and Surgeons, 630 W. 168 St., New York 32)

Scientists in the News

A. P. Elkin, emeritus professor of anthropology at the University of Sydney (Australia) has received the first Herbert E. Gregory medal for "distinguished service to science in the Pacific." The award, established by the trustees of the Bernice P. Bishop Museum in Honolulu, Hawaii, was presented at the 10th Pacific Science Congress (Honolulu, 21 Aug.–9 Sept.).

Recent awards of the American Heart Association:

Tinsley R. Harrison, of the Medical College of Alabama, and **Louis N. Katz**, of the Michael Reese Hospital in Chicago, will receive the 1961 Gold Heart awards, presented annually for "highly significant contributions to scientific understanding of the cardiovascular diseases, and to individuals who have rendered outstanding service in advancing the association's program."

The following science writers will receive the 1961 Howard W. Blakeslee awards for "outstanding reporting on diseases of the heart and blood vessels":

Mildred Spencer, for reporting in the Buffalo (N.Y.) *Evening News*.

James C. G. Coniff, of Upper Montclair, N.J., for his article in the August 1960 *Everywoman's Family Circle Magazine*.

Douglas Ritchie, of London, England, for his book entitled *Stroke*.

George W. Wharton, former head of the zoology department at the University of Maryland, has become chairman of Ohio State University's department of entomology and zoology.

Thomas F. Paine, Jr., professor and chairman of the department of microbiology at the University of Alabama Medical Center, has been appointed professor of medicine at Vanderbilt University and chief of the medical service at Nashville General Hospital.

Bruce F. Powers, physical chemist, and **Howard L. Wiener**, mathematician, have joined Massachusetts Institute of Technology's Operations Evaluation Group.

Ralph B. Hogan, chief of the laboratory branch in the U.S. Public Health Service's Communicable Disease Center in Atlanta, Georgia, has retired to become director of the Pennsylvania State Department of Health's division of laboratories. He is succeeded by **U. Pentti Kokko**, former deputy chief of the branch.

The following scientists will receive $5000 Gairdner Foundation (Toronto, Ontario) awards for their work in the treatment of arthritis and heart diseases:

Alan C. Burton, professor of biophysics at the University of Western Ontario.

Sir **Russell Brock**, cardiac surgeon at Guy's Hospital and Brompton Hospital, London, England.

Jonas H. Kellgren, professor and director of the rheumatism research center at the University of Manchester (England).

Alexander B. Gutman, director of the department of medicine at Mount Sinai Hospital, New York.

U. S. von Euler–Chelpin, professor of physiology at Karolinska Institutet in Stockholm, Sweden.

Mayhew Derryberry, head of the Public Health Service's health education activities, is serving a 6-week assignment as a special World Health Organization consultant to the Health Ministry of Japan.

Robert K. Crane, associate professor of biochemistry at the Washington University Medical School, has been appointed professor of biochemistry and chairman of the department at the Chicago Medical School.

Gustav J. Martin, biochemist, has been named director of National Research Associates' newly dedicated David Griffiths Memorial Laboratory of Basic Research.

Judith L. McKay, a biologist with the U.S. Public Health Service's National Institute of Arthritis and Metabolic Diseases, has been accepted for training in the Peace Corps. She will maintain a teaching and research post in Nigeria.

John T. Wilson, assistant director for biological and medical sciences at the National Science Foundation, has been appointed professor of psychology and special assistant to George W. Beadle, chancellor of the University of Chicago.

Hiroshima Revisited

Governments seek agreements to control the atom, but historians still disagree on its first military use.

Arthur H. Compton

It is a satisfaction to read the documented account of events in which one has participated, as told by an able historian who has access to papers that have long been hidden; but the distorted coloring that can be brought into such a story by a historian with a biased approach constitutes a warning of the caution with which even such an authenticated history must be read. In the two books before us, both of these aspects of written "history" are exemplified.

In **Japan Subdued** (Princeton University Press, Princeton, N.J., 1961. 206 pp. $4) Herbert Feis presents a serious study of the timing and an explanation of both the Allied demand for unconditional surrender and the decision to use the atomic bomb to compel that surrender more promptly. The author has made free and careful use of the collection of papers concerned with the Potsdam Conference, which were assembled by the State Department, and of various personal records not available to earlier students who reviewed the facts or the significance of these events. He has not hesitated to include his own judgments of the procedures followed, judgments that I consider well balanced.

Three methods are considered by which the war in the Pacific area might conceivably have been won: These were: (i) by combined assault by American, British, and Russian forces; (ii) by inducing the Japanese to accept an honorable surrender on liberal terms before they were compelled abjectly to do so; (iii) by using the atomic bomb to shock the Japanese into recognizing the inevitability of their disastrous defeat, and thus causing them to surrender before an expeditionary force invaded their home islands.

The evidence indicates that either of the latter two methods in the hands of the United States alone would have been adequate eventually to bring about surrender. But by using them in combination and with the cooperation of our British and Russian allies, the date of surrender was substantially advanced. In fact, Feis believes that both Russia's entry into the war and the cooperation of Britain and Canada in the preparation of the bomb were of marked help in advancing the timetable of peace negotiations.

Critical Factors

The author quotes, with evident approval, Robert Oppenheimer's testimony that the critical factors which determined the American decision to use the atomic bomb in Japan were "the belief that this would effect the saving of many lives of Americans and of Japanese and that the postwar world might thus be stabilized." This he supports by quotations from the memoirs of both Stimson and Churchill. Feis finds that the documents confirm Truman's contention that up to the last the American effort was directed toward bringing the Russians quickly into the war against Japan, with the hope of further shortening the war and thus saving many lives on both sides. He finds no evidence to support the view that the United States was trying to forestall the Russian entry into the Pacific War by prompt use of the bomb, but he notes that Russia commenced operations in Manchuria some weeks earlier than she had indicated she would, apparently motivated by the atomic bomb attack to achieve some military success before the Japanese could negotiate a surrender. He does not believe that Stalin was much surprised by Truman's word of American readiness with a new type of bomb, but he believes that our postwar relations with Russia might have been eased if Truman and Churchill had told Stalin candidly about the successful test explosion in New Mexico and of our intention to use the bomb on the Japanese early in August.

Without the use of the bomb, the Combined Chiefs were prepared to continue the war for more than another year. With the bomb available and with Britain and Russia fighting on the side of the United States, the author says that seldom has so crushing and relentless a combination of forces been arrayed against an enemy. Yet he notes "seldom has so large a residue of toleration remained."

Feis notes that the American government was fully aware of the tentative peace feelers the Japanese were extending to Russia during the spring and summer of 1945. To me this is a matter of some interest, because the scientists who were asked to advise the Interim Committee on various aspects of the use of the bomb were, as far as I know, given no inkling that such negotiations were being considered. It is clear, however, that our government was correct in its judgment that Japan was still far from ready to enter into any fruitful peace discussions and that these overtures were rather a step toward getting from Russia some preferred terms of settlement.

It is noteworthy that the tragic obstacles which have prevented an agreement on the international control of atomic weapons were clearly foreseen by Stimson as early as the spring of 1945, and that at the same time Bush, Conant, and the scientists at Chicago predicted the American advantage in nuclear armament would not last long.

Perhaps the most that can be said for this remarkable adventure of faith in the power of science to give the world a new start is that by demonstrating the effectiveness of its atomic bomb the United States made it possible to avoid any disastrous world conflict for the half generation many political observers have considered the most dangerous of our century. Feis' account of these events gives an impressive indication of the large amount of mutual consideration that underlies even the most drastic actions of modern governments.

The author, distinguished service professor of natural philosophy at Washington University, St. Louis, Mo., directed the work that resulted in the first atomic chain reaction.

Verbal Jockeying

Erwin Hiebert, an American with a Canadian background, is professionally interested in the history of science, but his book, **The Impact of Atomic Energy** (Faith and Life Press, Newton, Kans., 1961. 312 pp. $4) is primarily concerned with group reactions of governments, scientists, and religious bodies toward the development of nuclear weapons and the peaceful uses of nuclear energy. In his opening discussion Hiebert reviews the growth of knowledge of nuclear science during the early 20th century. In this summary he wisely attempts to correct the impression that this development was primarily an American achievement but shows that, in fact, it was rather an achievement of scientists throughout the world. In doing so, however, he frequently leans over backwards, slighting important contributions made by Americans. Thus he notes the observation by Joliot-Curie and his Parisian colleagues of the multiple emission of neutrons by uranium as a part of the fission process, but he neglects to note that the same phenomenon had been discovered earlier by Szilard and Zinn and that it became the spark that started the intensified American program leading to the first nuclear chain reaction. He fails to mention the American discovery of the delay in the emission of some of the neutrons, which made it possible safely to control the nuclear chain reaction, and he omits any description of the painstaking British-American studies of the energy dependence of the capture and collision of neutrons with various atomic nuclei. This study revealed the usefulness of graphite as a moderator for the nuclear reactor and also showed that an explosive nuclear bomb of limited size could probably be successfully constructed. He fails to mention the discovery by Seaborg and his California team, of the artificial element plutonium and its fission properties, which provided the reason for undertaking the whole reactor development. The author is correct in saying that in truth there was no nuclear arms race in the early 1940's between the Allies and Germany, though he fails to note that it was the American knowledge that the Germans were working intensively on problems of nuclear fission which spurred our scientists to make a supreme effort. He gives more weight than would most American scientists to Junck's claim that the German scientists were deliberately stalling Hitler's program of atomic research and notes rather the view that "the American scientists, overcome by a desire to accomplish a brilliant technical achievement, were persuaded into signing a pact with the devil."

The author's lack of balance in discussing the military aspects of atomic energy appears most sharply when he comments on the "deliberate, premeditated destruction" involved in the use of the bomb on Hiroshima. He seems oblivious to the fact that such destruction is an essential part of all war, even of defensive war. In discussing the reasoning that supported such use of the bomb, he fails to note what Feis selects as "the critical factors that determined the bomb's use": (i) that the power of Japan's military clique to make their nation again a military menace to the world must be destroyed and (ii) that the war be brought to a successful conclusion with a minimum loss of American and Japanese lives. This blindness appears again when he describes very sympathetically the efforts of the scientists at Chicago and Los Alamos to prevent the unannounced bomb attack on Japan. The writers of this appeal (Rabinovitch and Szilard) were greatly concerned about the unfavorable international sentiment such use of the bomb would stimulate and about the resulting difficulties that would develop in obtaining any effective international control over atomic weapons, but only passing allusion is made in their appeal to the hope of the military leaders that American lives might thus be saved. This matter of saving lives was of paramount importance to the Secretary of War, Stimson, and to his military staff, and it was prominent in the minds of the Scientific Panel (of nuclear scientists) as they drew up their recommendation to Stimson's civilian "Interim Committee" approving use of the bomb. This consideration of soldiers' lives is hardly mentioned in Hiebert's summary. Feis' history is in this regard a much better treatment.

Religious Groups

Hiebert is at his best when he discusses what is obviously closest to his heart, the responses of religious groups to the problems posed by nuclear energy. As representing the Catholic response, he quotes liberally from Thomas E. Murray, Catholic layman and former member of the Atomic Energy Commission. To Murray "the modern concept of 'total victory' meaning total enemy ruin or unconditional surrender has become the chief cause of war's immorality"; and this, he remarks, is a regression to a type of barbarism. The author comments that many Catholics do not support Murray's definition of a "just war." They have said that if the society we aim at cannot be brought about by large-scale violence, then discriminate small-scale violence will not help either. Both produce an atmosphere of conflict and disruption in which any attempt forcibly to impose ideas on large groups of people in the world is bound ultimately to fail. The author notes further that in 1945 the Vatican vigorously opposed the obliteration bombing of Hiroshima and Nagasaki on the ground that it provided no immunity for civilian populations. In the Encyclical of 6 December 1950, "Atomic Weapons," the Pope expressed the need for renewal of conscience, repression of passions, calming of hatreds, putting into practice the norms of justice, more equitable distribution of wealth, and reciprocal charity.

Especially noteworthy is Hiebert's quotation from a statement by the National Council of Churches in 1957, as adopted at a General Assembly in St. Louis: "Even when arming our nation, we believe, must persistently seek workable agreements for universal inspected, controlled, reduction and regulation of all armaments, including nuclear weapons. We believe that the accelerating arms race which now grips our world may lead directly to a war which will destroy civilization, and that efforts must be redoubled to realize the final goal of world-wide disarmament in the framework of the U.N." There was a further pronouncement by the General Board of the N.C.C., "The Churches and the Use of Nuclear Energy for Peaceful Responses," published in 1960: "We therefore deem it our Christian responsibility, as faithful stewards, to work for an orderly development of nuclear energy for peaceful purposes for the benefit of all mankind." The report goes on to commend the safety record that has been achieved, but to warn that strong efforts must be made to prepare reasonable safeguards against accidents and to take all protective and curative measures against in-

jury. The Council recommends wide dissemination of knowledge about the safety record, the dangers, and the safeguards involved.

Other quotations are made from the extreme fundamentalist American Council of Christian Churches, from the Union of American Hebrew Congregations, and from such pacifist groups as the American Friends Service Committee, the Brethren Service Committee, and the Mennonite Central Committee. These may be summarized by quoting a statement of the Executive Council of the Friends Committee on National Legislation. "The only realistic defense efforts are those which prevent a nuclear attack by abolishing war itself . . . we in the United States should use our time, energies and resources to prevent the bombs from falling and to build the conditions of lasting peace. This is our only real defense."

It is probably only an oversight that the author does not refer, as does Feis, to the fact that in its use of atomic weapons against Japan the American military forces showed no trace of revengeful passion and were eager to avoid the hand-to-hand fighting of invasion warfare, which would incite such passions.

If the reader discounts the antimilitary prejudice and the apparently anti-American bias of the author, he can find in Hiebert's account of the religious issues involved some illuminating discussion of the current politico-religious-military tangle of the world's affairs.

Hit and Target Theories

Studies on Quantitative Radiation Biology. K. G. Zimmer. Translated by H. D. Griffith. Oliver and Boyd, London, 1961. 124 pp. Illus. 15s.

Studies on Quantitative Radiation Biology is a translation by H. D. Griffith from the German version of a publication which appeared in the proceedings of the Mainz Academy of Science and Literature under the title "Studien zur quantitativen Strahlenbiologie" in August 1960. It is a very condensed discussion of a problem that has puzzled many radiation biologists, that is, the physical basis of the effects of radiation on living organisms. This short book is divided into six chapters. The first three chapters (Short historical review, Generalized formal hit "theory," and Target "theory") that emphasize the basic physical approaches to radiobiology should be most useful for radiation biologists. These chapters which also bring out the limitations of the physical approaches and their possible pitfalls should be required reading for anyone who wants to conduct quantitative studies in radiobiology.

The "hit" and "target" theories were first brought into prominence in the late 20's and early 30's when the application of quantum theory to physics caused many investigators to apply something equivalent to quantum theory to the study of the effects of ionizing radiation on biological materials. The hit theory was first developed by Dessauer, and later the mathematical background was formulated by Blau and Altenburger. Still later Crowther and others, especially Holweck and Lacassagne, gave it further support. The important development of this concept really has come through the publications of three investigators: Timofeeff-Ressovsky; Zimmer, the author of the present volume; and Delbrück.

It is rather interesting to reflect on the background of the three investigators. Timofeeff-Ressovsky is one of the world's most prominent geneticists. After his return to Soviet Russia from Berlin at the end of World War II, however, he began to investigate the effects of radioisotopes on biological systems. Delbrück has gone on and made his mark in the phage field, as well as in this field, and in many other fields of quantitative biology not necessarily connected with radiation. Zimmer is the only one of the three men who has continued to work in this field, and he is now one of the important investigators in radiation biology.

It is unfortunate that the "hit" and "target" theories have been so much neglected in the last few years. Both are very useful and helpful for interpreting radiation effects, especially if the investigator is interested in the quantitative aspects of the interaction of radiation and biological systems. They have not, however, always proved to be the most useful, especially with the entrance of biochemical approaches to modern radiation biology.

It is just this emphasis on the physical rather than the chemical approach that makes the fourth chapter, "Theories of action through diffusible agents," less convincing and less thorough than the first three chapters.

Finally, in the chapter "Recent developments," the author discusses electron spin resonance. I agree that electron spin resonance is a most promising approach and that the study of free radicals may some day give us a picture of what is happening when radiation is absorbed by a living substance. It is surprising, however, that so little attention is paid in this chapter to the quantitative aspects that are emphasized so well in the first three chapters.

In this volume there is very little mention of the biochemical aspects of radiation effects, especially the modern development of the chemistry of nucleic acids, the chemistry of protein synthesis, and the transfer of information from nucleic acids to proteins. All these new developments have become very important in biochemistry and also promise to become a possible key to the study of the mechanism of radiation effects. The investigator who goes into radiation biology must be conscious of the importance of the physical interpretation of radiation effects, which is so well emphasized in the first three chapters, but he also has to remember that, in the study of the basic mechanism of radiation effects, he must not ignore biochemical changes in metabolism, in synthesis of compounds, and in the sources of energy for the living cell which come about in the chain of events following the original absorption of the radiation. Only by an interplay of every possible approach is there any promise that we will some day understand the mechanism of radiation effects. As a matter of fact, radiation studies are so deeply bound up with the study of the syntheses of living cells, including their genetical makeup, that radiation studies will always lag slightly behind the basic biological, biochemical, and biophysical studies; but they have often shown also that they can open a new field and lead to an understanding of the function of living organisms.

I would recommend this book most highly to anyone who is interested in radiobiology and the quantitative aspects of the effects of physical energy on the function of living cells.

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CO_2 in Photosynthesis

Encyclopedia of Plant Physiology. vol. 5, part 1 and part 2, *The Assimilation of Carbon Dioxide*. W. Ruhland, Ed. Springer, Berlin, 1960. Part 1, xl + 1013 pp. Part 2, xvi + 868 pp. Illus. DM. 530.

The present volume represents the most ambitious treatment of photosynthesis attempted since the publication of Rabinowitch's monumental work, and it reflects the increasing attention given to this fascinating biological process by workers in diverse scientific disciplines. The most comprehensive coverage is given to the physical chemistry of photosynthesis, with critical reviews by Livingston, Franck, French, Witt, Kok, and others. The intermediary biochemistry of photosynthesis is treated in several chapters, many of which strongly emphasize the work and the views of a particular laboratory. In general, these cover the reactions of oxygen-producing plants; against this there is only one, but very excellent, chapter on photosynthetic bacteria (by Gest and Kamen), which is set apart in the second part of this volume together with an extensive treatment of the chemosynthetic bacteria (Larsen, Schlegal, Engle, and Umbreit).

Intermediary carbon metabolism of oxygen-producing plants is presented in detail by Calvin and Bassham, while partial and cell-free photosynthetic reactions are reviewed by Clendenning (Hill reaction), Kessler (photoreduction and oxygen production), Arnon (chloroplast reactions), and Simonis (phosphorylation). Comparative biochemistry receives due emphasis in the informative chapter on carotenoids by Goodwin and in the treatment of chlorophyll chemistry by Aronoff. Several chapters are devoted to the physiology of photosynthesis and form a link to the very extensive review of ecological observations, to which a major part of the second volume is devoted. The chapters on the ecology of photosynthesis provide a valuable treatment of this field, which, in this comprehensive fashion, has not been available for some time.

In keeping with the encyclopedic nature of this work, an overwhelming amount of well-established material is presented. At times, however, the very detail of this material appears to prevent clear statement of the problems which exist and which make the field of photosynthesis a dynamic field of research.

Unfortunately, the treatise was planned before the Emerson-Blinks two-light effect was generally known; it is treated briefly in the chapter by Haxo, and some of its theoretical implications are considered by Franck. Future reviews might usefully include a separate analysis of the application of biochemical genetics to the field of photosynthesis, and also a more extensive treatment of its enzymology.

The two parts of this volume contain a tremendous amount of useful information; the big price tag probably will prevent its widespread acquisition by individual research workers.

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20th Century Blend

Life Pictorial Atlas of the World. By the Editors of *Life* and Rand McNally. Time, New York; Rand McNally, Chicago, Ill., 1961. 600 pp. Illus. Regular ed., $30; deluxe ed., $35.

Here is the earth portrayed in maps, diagrams, colored photographs of relief model globes, and large landscape photographs. The resulting work is academically sound but occasionally jarringly garish and opulent.

Map makers are chronically troubled by the complexity of the world they study and the limited space in which the desired information is to be portrayed. One result of the ample budget allocated to this atlas is a near elimination of the latter problem. In this atlas a number of maps and diagrams are used to describe each area treated. The first sheet is a political map with place names and boundaries. It is old-fashioned in format. A second sheet shows land forms by a merged shaded relief technique. This sheet is color coded to show the type of vegetation. Succeeding smaller maps then show major resources, population distribution, or transport routes, as appropriate. In some cases, specific earth form cross sections, farm plans, or town plans are used. Photographs, which are frequently superb, highlight the significant features. The diverse maps and graphs are related by the terse, usually insightful, text.

The degree of detail in coverage varies from one area to another. Canada and the United States rate a two-page spread for each province or state. However, the entire Soviet Union is described in only eight pages plus a further four photographs. Mainland China is equally slighted. The impressions conveyed of these vast, complex, continent-spanning countries are far too simple.

This is an atlas of merit and one which was costly to produce. Regrettably the price is sufficiently high to limit its distribution to institutions.

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New Books

Mathematics, Physical Sciences, and Engineering

Academician V. I. Smirnov's Linear Algebra and Group Theory. Richard A. Silverman, Ed. McGraw-Hill, New York, 1961. 474 pp. Illus. $12.50.

Advances in Fluorine Chemistry. vol. 2. M. Stacey, J. C. Tatlow, and A. G. Sharpe, Eds. Butterworths, Washington, D.C., 1961. 220 pp. Illus. $8.

Advances in Geophysics. vol. 7. H. E. Landsberg and J. Van Mieghem. Academic Press, New York, 1961. 343 pp. Illus. $11.

Automat und Mensch. Uber menschliche und maschinelle Intelligenz. Karl Steinbuch. Springer, Berlin, Germany, 1961. 260 pp. Illus. DM. 28.50.

Basic Laws of Matter. H. S. W. Massey and Arthur R. Quinton. Herald Books, Bronxville, N.Y., 1961. 178 pp. $3.75.

The Chemical and Biological Action of Radiations. vol. 5. M. Haissingsky, Ed. Academic Press, London; Masson, Paris, 1961. 289 pp. Illus. $8.

The Climates of the Continents. W. G. Kendrew. Oxford Univ. Press, London, ed. 5, 1961. 608 pp. Illus. 55s.

The Determination of Stability Constants and Other Equilibrium Constants in Solution. Francis J. C. Rossotti and Hazel Rossotti. McGraw-Hill, New York, 1961. 439 pp. Illus. $12.50.

Electrical Contracting. Ray Ashley. McGraw-Hill, New York, 1961. 296 pp. Illus. $10.

Geometry Through Practical Applications. Julio A. Miro. Barnes and Noble, New York, 1961. 286 pp. Paper, $1.75.

Interfacial Phenomena. J. T. Davies and E. K. Rideal. Academic Press, New York, 1961. 487 pp. Illus. + plate. $14.

The Radiation Chemistry of Water and Aqueous Solutions. Augustine O. Allen. Van Nostrand, Princeton, N.J., 1961. 215 pp. Illus. $6.

Refractory Metals and Alloys. Metallurgical Society Conferences, vol. 11. M. Semchyshen and J. J. Harwood, Eds. Interscience, New York, 1961, 635 pp. Illus. $22.

Treatise on Analytical Chemistry. pt. 2, *Analytical Chemistry of the Elements*, vol. 5, *N, P, Th, Zn–HF*. I. M. Kolthoff and Philip J. Elving, Eds. Interscience, New York, 1961. 430 pp. Illus. $13.75.

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Mighty magnification

Forty bucks for a few rings and rods to put over the front of the new *Kodak Retina Reflex III Camera?**

A mite under, actually, at the camera shop. Also includes an auxiliary lens. All nicely fitted together. Called the Kodak Retina 1:1 Copying Kit. *Switch the f/2.8 lens from the camera to the kit, snap the kit onto the camera, attach the auxiliary lens and the camera's lens hood, set the diaphragm between f/11 and f/22 and the distance scale at 5 feet. Snap, swish—just like that. Make pictures. Anything in the plane of the rectangular opening is focussed on the film same size. Depth of field at f/22 is 5.5 mm. When resulting slide is projected, magnification is mighty and can be useful for mensuration if a calibrating scale has been included in the picture. Handy for picturing platyhelminthes, coins, microcircuitry, the triumphant crystals of a new enzyme you have isolated. Kit also includes a slide holder and diffusion screen for making your own black-and-white duplicates of color slides.*

If you can make this kit yourself for less than $40, you are too clever a fellow to be working that cheap.

A sharp eye for infrared

The decision to announce at this time the availability of *f*/1 *Irtran-2 Aspheric Lenses* has been reached in struggle against deeply rooted inhibitions. In the photographic film and paper trade we are habituated to a longer silence before the first blast of the trumpets. Infrared technology hates to wait, however, and puts a heavy load on the phone company's long lines.

These Irtran-2 lenses transmit usefully from 2μ to 14μ. Two focal lengths, 2-inch and 3-inch, are offered off the shelf. At *f*/1, we seem to have done well at providing high collecting-power for energy without undue sacrifice of sharpness. Sharpness was the goal. For both lenses, the minimum circle of confusion *computes* at less than .001″ for any wavelength from 4.25μ to 10μ. The italics mark where we hurt.

Much care and a valuable ingenuity have been exercised in impressing our tenth-degree equation upon the concave side of these meniscus lenses, in grinding and polishing the spherical convex side, in placing the center of the spherical curvature on the axis of the asphere, in maintaining the center thicknesses at the 9.1 mm and 10.4 mm values respectively that the calculations assume, in the optical homogeneity of the Irtran-2 material. More than this we cannot claim. To the extent that the care and ingenuity have succeeded in making the calculations represent the actuality, the circle of confusion is less than .001″. The customer's willingness to take a chance that we have hit it will, in good sense, depend on how badly his project needs a 2μ-14μ infrared image of high definition and high aperture.

To demonstrate experimentally at those wavelengths that the circle of confusion is indeed that small is a task which we have simply been too busy to complete up to the time these words were written.

In the lead sulfide region, the sharpness does not compute to be as good as farther out in the infrared. Yet we have customers who use the lenses there and are happy with confusion-circle minima as large as .008″.

In comparison with reflective optics hitherto used, Irtran-2 aspheres offer compactness and a wider field that doesn't even show any appreciable deterioration as far as 2° off axis. You do give up the perfect achromatism of reflective optics. In the 2-inch lens the minimum circle of confusion for 10μ radiation is located 2 mm beyond the minimum circle of confusion for 4.25μ radiation; in the 3-inch lens the separation is 3 mm.

We have said enough to establish our frankness and to indicate whether there is any need for you to burden the long lines to Rochester, N. Y., LOcust 2-6000, Extension 5166, which is one way to reach Eastman Kodak Company, Special Products Division. Bear in mind that Irtran-2 material has a hardness of 354 Knoop, is not at all brittle, withstands thermal shock and the solvent action of water, and can get very hot without losing transparency or giving off toxic fumes.

An isonitroso more or less

In 1958 we set out to make a certain nickel reagent we had read about. Our method failed. It hung three instead of two isonitroso groups onto a monomethylated cyclohexane ring. We meekly advertised that we had *5-Methyl-1,2,3-cyclohexanetrione Trioxime* for sale as Eastman 7478 and hoped somebody would discover what *it* is a reagent for. (Some are amused by our candor in these matters.) The ad mentioned that in seeking the cause of our failure we had repeated our procedure on the unsubstituted ring and had similarly obtained *1,2,3-Cyclohexanetrione Trioxime*, which we designated Eastman 7660.

The sad little sigh with which we closed the discussion spread out over the world. A friendly echo has now returned from Agnes Scott College, Decatur, Ga. Four sympathetic chemists there startle us by reporting that Eastman 7660 forms a very stable and spectrophotometrically convenient complex with cobalt at an optimum concentration range of 1 to 4 p.p.m.

Reading this (*Anal. Chem. 33*, 1096), we checked to make sure old 7660 was still there and were again astonished to find that the original batch had sold down to inventory minimum! We now have a new batch, a free abstract of the cobalt determination, and a feeling that purposeful planning serves chiefly to comfort the soul.

Nevertheless, List No. 42 of some 3900 Eastman Organic Chemicals we stock can serve some useful purpose in planning. For a copy or for the cobalt determination abstract, write Distillation Products Industries, Rochester 3, N. Y. (Division of Eastman Kodak Company).

Price subject to change without notice.

*Most versatile 35mm camera we make. Also works with *Kodak Retina Reflex S* and *IIIS Cameras*. Kit designed for *f*/2.8 models only.

Kodak
TRADE MARK

This is another advertisement where Eastman Kodak Company probes at random for mutual interests and occasionally a little revenue from those whose work has something to do with science

Meetings

Forthcoming Events

November

6–8. Chemical Engineering Div., Chemcal Inst. of Canada, Toronto, Ont. (CIC, 48 Rideau St., Ottawa 2, Ont.)

6–9. Atomic Industrial Forum–9th Hot Laboratories and Equipment Conf., Chicago, Ill. (O. J. Du Temple, American Nuclear Soc., 86 East Randolph St., Chicago)

8. American Acad. of Arts and Sciences, Brookline, Mass. (J. L. Oncley, 280 Newton St., Brookline 46)

8–11. Acoustical Soc. of America, Cincinnati, Ohio. (W. Waterfall, American Inst. of Physics, 335 E. 45 St., New York 17)

8–11. Institute of Management Sciences, San Francisco, Calif. (W. Smith, Inst. of Science & Technology, Univ. of Michigan, Ann Arbor)

8–11. Plasma Physics, American Physical Soc., 3rd annual, Colorado Springs, Colo. (F. Ribe, Los Alamos Scientific Laboratory, P.O. Box 1663, Los Alamos, N.M.)

9–10. Operations Research Soc. of America, 20th, San Francisco, Calif. (P. Stillson, 115 Grove Lane, Walnut Creek, Calif.)

9–11. Gerontological Soc., Pittsburgh, Pa. (R. W. Kleemeier, Washington Univ., Skinker and Lindell, St. Louis 30, Mo.)

9–12. Pacific Coast Fertility Soc., Palm Springs, Calif. (G. Smith, 909 Hyde St., San Francisco 9, Calif.)

9–20. Photography, Cinematography, and Optics, 3rd intern. biennial, Paris, France. (Comité Francais des Expositions, 15 rue de Bellechasse, Paris 7)

12–17. Bahamas Conf. on Medical and Biological Problems in Space Flight, Nassau, Bahamas. (I. M. Wechsler, P.O. Box 1454, Nassau)

13–14. Exploding Wire Phenomenon, 2nd intern. conf., Boston, Mass. (W. G. Chace, Thermal Radiation Laboratory, CRZCM, Geophysics Research Directorate, Air Force Cambridge Research Laboratories, Bedford, Mass.)

13–16. Magnetism and Magnetic Materials, 7th annual intern. conf., Phoenix, Ariz. (P. B. Myers, Motorola, Inc., 5005 E. McDowell Rd., Phoenix 10)

13–17. American Public Health Assoc., 89th annual, New York, N.Y. (APHA, 1790 Broadway, New York)

13–17. Gulf and Caribbean Fisheries Inst., 14th annual, Miami Beach, Fla. (J. B. Higman, Marine Laboratory, Univ. of Miami, 1 Rickenbacker Causeway, Virginia Key, Miami 49)

13–18. European Conf. on the Control of Communicable Eye Diseases, Istanbul, Turkey. (World Health Organization, Palais des Nations, Geneva, Switzerland)

14–16. American Meteorological Soc., Tallahassee, Fla. (Executive Secretary, AMS, 45 Beacon St., Boston 8, Mass.)

14–17. Corrosion in Nuclear Technology, symp., Paris, France. (European Federation of Corrosion, Société de Chimie Industrielle, 28 rue St. Dominique, Paris 7°)

14–18. Puerto Rico Medical Assoc., Santurce. (J. A. Sanchez, P.O. Box 9111, Santurce)

15–17. Eastern Analytical Symp., New York, N.Y. (A. Rekus, EAS, Research Dept., Baltimore Gas & Electric Co., Pratt St., Baltimore, Md.)

15–18. Society of Naval Architects and Marine Engineers, annual, New York, N.Y. (W. N. Landers, SNAME, 74 Trinity Pl., New York 6)

16–18. American Psychiatric Assoc., Milwaukee, Wis. (J. D. McGucken, 756 N. Milwaukee St., Milwaukee 2)

16–18. Etiology of Myocardial Infarction, intern. symp. (by invitation), Detroit, Mich. (T. N. James, Section on Cardiovascular Research, Henry Ford Hospital, Detroit)

16–18. Southern Thoracic Surgical Assoc., Memphis, Tenn. (H. H. Seiler, 517 Bayshore, Blvd., Tampa 6, Fla.)

16–19. American Anthropological Assoc., Philadelphia, Pa. (S. T. Boggs, 1530 P St., NW, Washington, D.C.)

17–18. Southern Soc. for Pediatric Research, Atlanta, Ga. (W. G. Thurman, Dept. of Pediatrics, Emory Univ. School of Medicine, Atlanta)

17–31. National Soc. for Crippled Children and Adults, annual conv., Denver, Colo. (NSCCA, 2023 W. Ogden Ave., Chicago 12, Ill.)

19–22. International College of Surgeons, Western regional, San Francisco, Calif. (W. F. James, 1516 Lake Shore Drive, Chicago 10, Ill.)

22–27. Automation and Instrumentation, 5th conf., Milan, Italy. (Federezione delle Societa Scientifiche e Techniche di Milano, via S. Tomaso 3, Milan)

22–1. Radioisotopes in Animal Biology and the Medical Sciences, conf., Mexico City, D.F. (International Atomic Energy Agency, 11 Kärntner Ring, Vienna 1, Austria)

23–25. Central Assoc. of Science and Mathematics Teachers, Chicago, Ill. (J. Kennedy, Indiana State Teachers College, Terre Haute)

24–25. American Soc. of Animal Production, Chicago, Ill. (C. E. Terrill, Animal Husbandry Research Div., U.S. Dept. of Agriculture, Beltsville, Md.)

24–25. National Council for Geographic Education, Philadelphia, Pa. (L. Kennamer, Dept. of Geography, Univ. of Texas, Austin)

25–26. American College of Chest Physicians, annual interim session, Denver, Colo. (M. Kornfeld, ACCP, 112 E. Chestnut St., Chicago 11, Ill.)

26. Medical Aspects of Sports, 3rd natl. conf., Denver, Colo. (F. V. Hein, AMA Committee on the Medical Aspects of Sports, 535 N. Dearborn St., Chicago 10, Ill.)

26–1. American Soc. of Mechanical Engineers, winter, New York, N.Y. (L. S. Dennegar, ASME, 29 W. 39 St., New York, N.Y.)

26–1. Radiological Soc. of North America, annual, Chicago, Ill. (R. P. Barden, 713 E. Genesee St., Syracuse 2, N.Y.)

27–28. Agricultural Meteorology, 4th conf., St. Louis, Mo. (K. C. Spengler, American Meteorological Soc., 45 Beacon St., Boston 8, Mass.)

27–29. American Soc. of Hematology,

annual, Los Angeles, Calif. (J. W. Rebuck, ASH, Henry Ford Hospital, Detroit 2, Mich.)

27–30. American Medical Assoc., Denver, Colo. (F. J. L. Blasingame, 535 N. Dearborn, Chicago 10, Ill.)

27–30. American Soc. of Agronomy, jointly with Crop Soc. of America, Council on Fertilizer Application, and Soil Science Soc. of America, St. Louis, Mo. (ASA, 2702 Monroe St., Madison, Wis.)

27–30. Entomological Soc. of America, Miami, Fla. (R. H. Nelson, 4603 Calvert Rd., College Park, Md.)

29–1. Communication Wires and Cables, symp., Asbury Park, N.J. (H. Kingsley, U.S. Army Research and Development Laboratory, Fort Monmouth, N.J.)

29–1. Western Surgical Assoc., San Francisco, Calif. (W. W. Carroll, 700 N. Michigan Ave., Chicago 11, Ill.)

30. American Geographical Soc., New York, N.Y. (C. W. Bastable, Columbia Univ., New York 27)

30–1. Conference on Graduate Medical Education, Philadelphia, Pa. (P. Nemir, Jr., Dean, Graduate School of Medicine, Univ. of Pennsylvania, Philadelphia)

30–1. Vehicular Communications, Minneapolis, Minn. (J. Kahnke, Minneapolis-Honeywell, Aero Div., 1541 Edgewater Ave., St. Paul 13, Minn.)

30–2. Purest Substances in Science and Technology, intern. symp., Dresden, Germany. (Sekretariat, Chemische Gesellschaft in der Deutschen Demokratischen Republik, Unter den Linden 68/70, Berlin W.8, Germany)

December

1. Symposium on Insulin, New York Diabetes Assoc., New York, N.Y. (New York Diabetes Assoc., 104 E. 40 St., New York 16)

1–2. Linguistic Circle of New York, 7th annual conf., New York, N.Y. (L. Urdang, Random House, Inc., 501 Madison Ave., New York 22)

2. International College of Surgeons, intern. executive council, Chicago, Ill. (H. E. Turner, 1516 Lake Shore Dr., Chicago 11)

2. New York State Registry of Medical Technologists, annual seminar, New York, N.Y. (S. H. Keeling, 1719 Midland Ave., Syracuse, N.Y.)

2–7. American Acad. of Dermatology and Syphilology, annual, Chicago, Ill. (R. R. Kierland, Mayo Clinic, Rochester, Minn.)

3–6. American Inst. of Chemical Engineers, New York, N.Y. (F. J. Van Antwerpen, AICE, 345 E. 47 St., New York 17)

4–6. Institute of the Aerospace Sciences, Aerospace Support and Operations, natl., Orlando, Fla. (R. J. Kotowski, 318 Virginia Dr., Melbourne, Fla.)

4–8. International Colloquium on Ionic Bombardment, Bellevue, France. (Natl. Scientific Research Center, 15 Quai Anatole France, Paris 7°, France)

4–9. Mathematics Instruction at Secondary and University Levels, Inter-American conf., Bogota, Colombia. (M. Alonso, Div. of Science Development, Pan American Union, Washington 6)

4–9. World Federation of Neurology, Problem Commission of Tropical Neurology, Buenos Aires, Argentina. (P. Bailey, Natl. Inst. of Neurological Diseases and Blindness, Bethedsa, Md.)

4–16. Inter-American Conf. on Education and Economic and Social Development, Santiago, Chile. (U.S. National Commission for UNESCO, Dept. of State, Washington 25)

4–16. Latin American Phytotechnical Meeting, 5th, Buenos Aires, Argentina. (U. C. Garcia, Organizing Committee, Rivadavia 1439, Buenos Aires)

5–7. Building Research Inst., Washington, D.C. (Scientific Liaison Office, Natl. Research Council, Sussex Dr., Ottawa, Canada)

6–7. UNESCO Intern. Non-Governmental Organizations on Extension of Intern. Collaboration in Education, Science and Culture to Africa, Paris France. (Place de Fontenoy, Paris 7°)

6–8. Electrical Furnace Steel Conf., 19th, American Inst. of Mining, Metallurgical and Petroleum Engineers, Pittsburgh, Pa. (Scientific Liaison Office, Natl. Research Council, Sussex Dr., Ottawa, Canada)

6–8. Latin-American Congr. of Pathological Anatomy, 3rd, Medellín, Colombia. (A. C. Henao, Laboratorio de Anatomía Patológica, Rua Botucatu 720, São Paulo, Brazil)

6–8. Conference on Document Copying by Photography, London, England. (A. J. O. Axford, Ozalid Co., Longston Rd., Loughton, Essex, England)

6–8. National Institutes of Health Symp. on Neuroendocrinology, Miami, Fla. (A.

V. Nalbandov, 102 Animal Genetics, Univ. of Illinois, Urbana)

6–12. American Acad. of Optometry, Chicago, Ill. (C. C. Koch, 1506–08 Foshay Tower, Minneapolis 2, Minn.)

6–16. Food and Agriculture Organization of the U.N. World Health Organization, Nutrition Conf. for the Far East, 5th, Hyderabad, India. (Intern. Agency Liaison Branch, Office of Director General, FAO, Viale delle Terme di Caracalla, Rome, Italy)

6–16. Food and Agriculture Organization of the U.N., Far East Meeting on Animal Production and Health, 3rd, Bangkok, Thailand. (Intern. Agency Liaison Branch, Office of Director General, FAO, Viale delle Terme di Caracalla, Rome, Italy)

7–8. Symposium on Sintered High-Temperature Oxidation-Resistant Materials, London, England. (S. C. Guilan, Powder Metallurgy Joint Group, Inst. of Metals, 17 Belgrave Sq., London)

7–9. American Chemical Soc. Southwest-Southeast regional meeting, New Orleans, La. (P. D. Accardo, California Chemical Co., Oronite Div., Belle Chasse, La.)

7–9. New York Acad. of Sciences Conf. on the Cervix, New York, N.Y. (W. R. Lang, Jefferson Medical College, Philadelphia, Pa.)

7–9. Texas Acad. of Science, Galveston. (D. E. Edmondson, Mathematics Dept., 115 Bendect Hall, Univ. of Texas, Austin 12)

8. Food and Agriculture Organization of the U.N., Advisory Group on Training in Home Economics and Social Work, Rome, Italy. (Intern. Agency Liaison Branch, Office of Director General, FAO, Viale delle Terme di Caracalla, Rome)

8–9. Symposium on Plasma Membrane, New York, N.Y. (A. P. Fishman, New York Heart Assoc., 10 Columbus Circle, New York 19)

8–9. American Rheumatism Assoc., interim session, Washington, D.C. (F. E. Demartini, 622 W. 168 St., New York 32)

8–9. Association for Research in Nervous and Mental Diseases, annual, New York, N.Y. (Scientific Liaison Office, Natl. Research Council, Sussex Dr., Ottawa, Canada)

8–10. American Psychoanalytic Assoc., New York, N.Y. (D. Beres, 151 Central Park W., New York 23)

9–10. Academy of Psychoanalysis, New York, N.Y. (J. H. Merin, 125 E. 65 St., New York 21)

10–13. American Phytopathological Soc., Biloxi, Miss. (G. A. Zentmyer, Dept. of Plant Pathology, Univ. of California, Riverside)

11–15. Agricultural and Public Health Aspects of Radioactive Contamination in Normal and Emergency Situations, technical seminar, The Hague, Netherlands. (Food and Agriculture Organization of the U.N., Intern. Agency Liaison Branch, Office of the Director General, Viale delle Terme di Caracalla, Rome, Italy)

11–15. Symposium on Organization of Agricultural Research, Muguga, Kenya. (Commission for Technical Cooperation in Africa South of the Sahara, Pvt. Mail Bag 2359, Lagos, Nigeria)

11–16. Ionospheric Soundings in the In-

tern. Geophysical Year/Intern. Geophysical Cooperation–1959 Symp., Nice, France. (A. H. Shapley, URSI World-Wide Soundings Commission, Central Radio Propagation Laboratory, Natl. Bureau of Standards, Boulder, Colo.)

12–14. Association for Computing Machinery, Eastern joint computer conf., Washington, D.C. (B. Oldfield, I.B.M. Corp., 326 E. Montgomery, Rockville, Md.)

12–15. American Soc. of Agricultural Engineers, Chicago, Ill. (J. L. Butt, ASAE, 420 Main St., St. Joseph, Mich.)

12–19. Latin American Congr. on Microbiology, 2nd, San Jose, Costa Rica. (J. de Abate, Apartado 1404, San Jose)

13. American Acad. of Arts and Sciences, Brookline, Mass. (J. L. Oncley, 280 Newton St., Brookline 46)

15–16. Oklahoma Acad. of Science, Stillwater. (D. Buck, Northern Oklahoma Junior College, Tonkawa)

17–18. International Congr. of Comparative Pathology, 9th, Paris, France. (L. Grollet, Comité International Permanent des Congrès de Pathologie Compareé, 63 Avenue de Villiers, Paris 17°)

19–23. Inter-American Congr. of Psychology, 7th, Monterrey, Mexico. (G. M. Gilbert, Psychology Dept., Long Island Univ., Brooklyn 1, N.Y.)

22–29. Plant Tissue and Organ Culture, intern. symp., New Delhi, India. (P. Maheshwari, Univ. of Delhi, Delhi)

26–28. History of Science Soc., annual, Washington, D.C. (J. C. Greene, 1121 Iowa Ave., Ames, Iowa)

26–31. American Assoc. for the Advancement of Science, annual, Denver, Colo. (R. L. Taylor, AAAS, 1515 Massachusetts Ave., NW, Washington 5)

27–29. American Folklore Soc., Cincinnati, Ohio. (T. P. Coffin, 110 Bennett Hall, Univ. of Pennsylvania, Philadelphia 4)

27–29. American Geophysical Union, 1st Western natl., Los Angeles, Calif. (A. N. Sayre, U.S. Geological Survey, Washington 25)

27–29. American Economic Assoc., New York, N.Y. (J. W. Bell, AEA, Northwestern Univ., Evanston, Ill.)

27–29. American Physical Soc., Los Angeles, Calif. (K. K. Darrow, 538 W. 120 St., New York 27)

27–29. Western Soc. of Naturalists, Eugene, Ore. (I. A. Abbott, Hopkins Marine Station, Pacific Grove, Calif.)

27–30. Institute of Mathematical Statistics, annual, New York, N.Y. (D. C. Riley, American Statistical Assoc., 1757 K St., NW, Washington 6)

28–29. Northwest Scientific Assoc., Spokane, Wash. (E. J. Larrison, Univ. of Idaho, Moscow)

28–29. American Chemical Soc., Div. of Industrial and Engineering Chemistry, Newark, Del. (Scientific Liaison Office, Natl. Research Council, Sussex Dr., Ottawa, Canada)

28–29. Linguistic Soc. of America, annual, Chicago, Ill. (A. A. Hill, Box 7790 University Station, Austin 12, Texas)

28–30. Archaeological Inst. of America, Detroit, Mich. (L. A. Campbell, 5 Washington Square N., New York 3)

28–30. Phi Delta Kappa, Bloomington, Ind. (R. S. Merkel, Indiana Central College, Indianapolis 27)

New Products

Leak detector tests hermetically sealed components for leaks in the range of 10^{-11} atm/cm³ sec. Testing is performed in two stages. During the activation stage, components are sealed in a lead-lined chamber and flooded with radioactive tracer gas, krypton-85, under pressures up to 200 lb/in.² (gage). Detection sensitivity is proportional to soak time, specific activity, and the square of the activation gas pressure differential. After the soak period, the tracer gas is removed, components are air washed, and the chamber is returned to atmospheric pressure. Inspection is performed with a scintillation counter that measures the radiation level. The presence of tracer gas is indicated on an auxiliary rate meter. The equipment can be adjusted to process automatically a wide variety of devices. Individual test programs are set on a master control panel. (Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.)

Circle 1 on Readers' Service card

Digital computer simulator tests and evaluates complete memory systems for a wide range of operating parameters. The tester accommodates random access memories or serial buffers with address capacities to 16,384 words and word lengths to 48 bits. Four major functions are provided: timing generation, word generation, address generation, and word register and error detection. Timing generation controls the tester as well as the memory that is being tested. Word generation controls the word length and the data contained in each word. The pattern generated can contain any number of ones or zeros provided there is only one transition from logical one to logical zero. The address generator consists of a 14-bit binary counter organized to be used in any of three modes: as a binary-coded decimal counter; as two seven-bit counters, in memories with two modes of address; or as a straight binary counter. The address counter can be set to count between any two addresses. The memory word register is a flip-flop register. For checking, this register is compared with the word generation portion of the tester. Depending on the mode of operation, when an error occurs, the tester will stop or count the error and continue. (Rese Engineering, Inc., A and Courtland Sts., Philadelphia, Pa.)

Circle 2 on Readers' Service card

Interferometer spectrometer (Fig. 1) analyzes the spectrum of incoming infrared radiation by converting each frequency element into a proportional electrical signal frequency in the range susceptible to electronic spectrum analysis. The interferometer is of the Michelson type which uses two mirrors, a beam splitter, and an infrared detector that observes the central fringe of the interference pattern. One of the mirrors is actuated by a saw-tooth signal to move repetitively at a uniform velocity. A monochromatic radiation signal entering the interferometer results in an electrical output from the radiation detector. The frequency of this output is related to the frequency of the input radiation as the velocity of the mirror is related to the velocity of light. A polychromatic radiation input similarly results in a superimposed "polychromatic" electrical output.

Since the electrical output is in the appropriate frequency range, a variety of techniques used for radio- or audio-frequency spectrum analysis can be applied. One such technique is the recording of the signal on magnetic tape and subsequent playback through a conventional wave analyzer. The result is a chart record of the spectrum of the radiation. Alternatively, the magnetic-recording step can be eliminated, with some sacrifice of resolution, by feeding the signal from the interferometer directly into a panoramic wave analyzer. If one is interested only in specific wavelengths, several tuned narrow-band filters can be placed in the output to indicate continuously the energy level at each of the wavelengths. If desired, the interferogram can be converted into digits, and then Fourier analysis can be performed by a computer.

An advantage claimed for the spectrometer is the increase of sensitivity resulting from the combination of two factors, (i) the large entrance aperture as compared with slit instruments and (ii) the continuous examination of all wavelengths throughout the entire period of each scan. The former is said to increase the sensitivity by a factor of 100 for extended sources and typical instruments. The latter results in an improvement in the signal-to-noise ratio (that according to information theory is proportional to the square root of the measuring time); it is said to be as much as 50 for typical instruments. This gain in sensitivity is paid for by a corresponding increase in the time required to perform the complete analysis.

The instrument consists of an optical head, housing the interferometer optics and measuring 2.5 by 2.5 by 8 in., and an electronics package measuring 6 by 8 by 10 in. Scanning rate is four spectra per second. If fluctuation of the source radiation is too rapid for this rate of

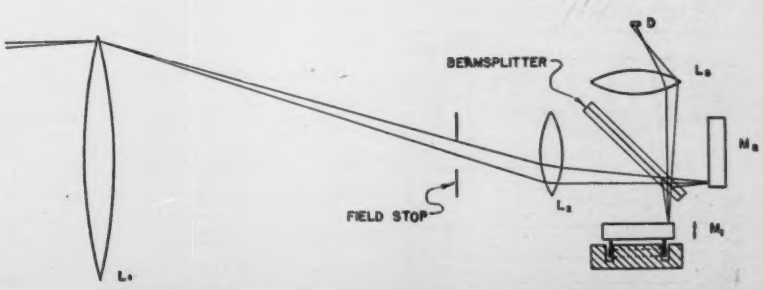


Fig. 1. Ray trace for interferometer spectrometer.

scan, resolution will be lost, but the correct relative shape of the spectral distribution curve will still be shown. Different detectors can be used simultaneously to cover a very broad spectral region in one output channel. Resolution is said to be 0.004 μ at 1 μ. (Block Associates, Inc., 385 Putnam Ave., Cambridge 39, Mass.)

Circle 3 on Readers' Service card

Card reader for automatic control systems will transport IBM cards from a card hopper past two reading stations and into a card stacker at a rate of 30 cards per minute. The cards are scanned row by row, and contact-closure outputs are provided corresponding to the perforations in all 80 columns of both cards. The reader will accept cards perforated in any binary or alphanumeric code and may be operated either from an integral control panel or by a remote automatic control system. (Datex Corp., 1307 Myrtle Ave., Monrovia, Calif.

Circle 4 on Readers' Service card

Universal ratio set is a six-dial instrument designed for calibration of d-c potentiometers and Wheatstone bridges. Ranges are $20 \times 100 + 10(10 + 1 + 0.1 + 0.01 + 0.001)$ ohms, for a total resistance of 2111.11 ohms. Limit of error at 25°C is said to be 0.002 percent for dial changes of 100 ohms or more; below 100 ohms, accuracy of reading is within two steps on the 0.001 dial (Leeds and Northrup Co., 4939 Stenton Ave., Philadelphia 44, Pa.)

Circle 5 on Readers' Service card

Neutron generator is a portable device that can be turned on and off at will. Heart of the generator is a neutron source tube with a cylindrical titanium-tritium target screen. Output of neutrons is approximately 10^8 per second with a neutron energy of 14.5 Mev. Outside dimensions are 4-in. diameter and 37-in. length; weight is 32 lb. The device operates on 115-volt 60-cy/sec current. (Dresser Industries Inc., Republic National Bank Bldg., Dallas, Tex.)

Circle 6 on Readers' Service card

Evaporated film thickness monitor depends on the measurement of the optical performance of the material being deposited. This is accomplished by projecting a chopped beam of white light upon a monitor disk in the vacuum chamber and measuring reflectance. Measurement is made at a specific wavelength corresponding to any of six

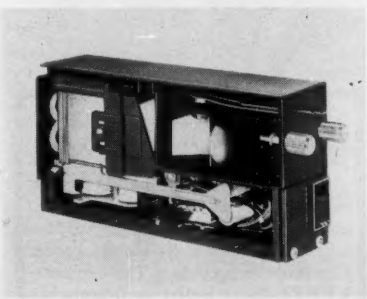
interchangeable filters. The component of the monitoring disk is installed through a ½-in. hole in the base of the vacuum chamber. The light beam, chopped at 90 cy/sec, is transmitted through the side of glass vacuum chambers or through a port in metal chambers. A two-channel amplifier permits addition of a second optical monitor system without additional electronics. The system is sensitive to infrared and visible radiation. Two red filters are supplied between 1.5 and 2.5 μ. Accuracy is said to permit control of film thickness to ± 0.25 percent. (Optics Technology, Inc., 248 Harbor Blvd., Belmont, Calif.)

Circle 7 on Readers' Service card

Lecture table oscilloscope features a 12-in. screen that faces the class and a 3-in. monitor and oscilloscope control on the rear panel for the instructor's convenience. All controls operate the two displays simultaneously. The electron beam of the 12-in. tube can be broadened and brightened to provide a wide trace said to be visible from any part of the largest classroom. Operating characteristics are otherwise very similar to the manufacturer's model 2167 oscilloscope. (Welch Scientific Co., 1515 Sedgwick St., Chicago 10, Ill.)

Circle 8 on Readers' Service card

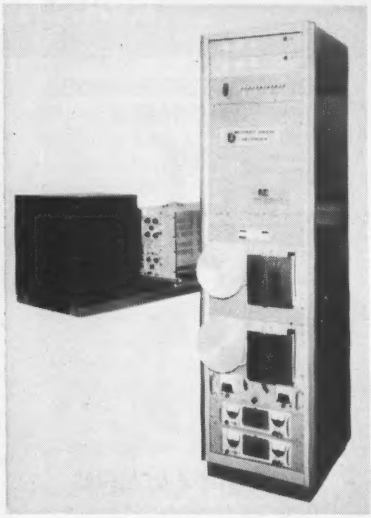
Alpha-numeric readout device accepts binary-coded decimal input up to six bits, decodes the input signal, and displays the proper character. Operating power is 10 mw per bit of signal. Up to 20 characters per second can be displayed; size of characters is 1⅜ in. The last character presented will remain



on display after signal-pulse and set-pulse power have been removed. Contact closures can be provided for verification that the input signals have been properly accepted. (Industrial Electronic Engineers, Inc., 5528 Vineland Ave., North Hollywood, Calif.)

Circle 9 on Readers' Service card

This **pattern converter** transforms information from an analog display, such as map, chart, oscilloscope, or graph, into digital *x-y* coordinate scan points. Output can be to punched cards, punched paper tape, or magnetic tape; or the equipment can be operated on-line with a computer. The instrument



breaks down an image of the display into a suitably fine grid, 0.05 in. per element in one model, and the blackness of each point and its position are converted to a digital code. Rate of conversion is determined by the system resolution requirements and the speed of the digital output devices. (Rabinow Engineering Co., 7212 New Hampshire Ave., Washington 12, D.C.)

Circle 10 on Readers' Service card

Beryllium analyzer includes a five-decade scaler, detector head, and lead chamber. In operation, gamma radiation from an antimony-124 source interacts with the sample, carried in a sample slide, to produce neutrons. The neutrons are detected by a scintillation counter, and the count rate is compared with that obtained with a standard sample to determine the beryllium content of the unknown. (Research Chemicals Division, Nuclear Corporation of America, Burbank, Calif.)

Circle 11 on Readers' Service card

Remote control stereomicroscope incorporates the manufacturers zoom optical system. Magnification is continuously adjustable between 1 and 60. A sealing tube permits the instrument to be repositioned at different points in a hot cell without danger of contamination. Self-contained shielding, equivalent

to 12 in. of lead, protects the operator from radiation from the cell access port when the instrument is in position. The standard model is designed for use in a 36-in. wall. Modifications permit installation in walls up to 60 in. thick. Supplied as standard equipment is a 35-mm stereo camera in a swing-on bracket that fits light tight over the eyepieces. (Bausch & Lomb Inc., Rochester 2, N.Y.)

Circle 12 on Readers' Service card

Accessory for x-y plotter adapts the manufacturer's model 560R plotter for on-line operation with medium scale digital computers. The adapter accepts incremental computer output signals and converts them to plotter input signals. The adapter provides the proper termination for the computer output lines, and, where required, returns a signal to the computer to request the next pulse. (California Computer Products, Inc., 8714 Cleta St., Downey, Calif.)

Circle 13 on Readers' Service card

Speech compression system is said to be capable of communicating speech in a total bandwidth of 150 cy/sec. When digitized, the compressed speech signal can be transmitted at an information rate of 1000 bits per second. In analog form, the signal appears as seven 20-cy/sec bandwidth low-passed signals. For digitizing, each of the channels is sampled at a 43.5-cy/sec rate to produce a single-channel stream of 1000 bits per second. The current model weighs less than 50 lb. (Melpar, Inc., Falls Church, Va.)

Circle 14 on Readers' Service card

Temperature transducer of the platinum resistor type is designed for indefinite immersion in sea water. The transducer contains its own bridge circuit. Calibration is expressed as millivolts per volt versus temperature over the range −5° to +30°C. Accuracy and interchangeability are said to be ±0.09°C. (Trans-Sonics, Inc., P.O. Box 328, Lexington, Mass.)

Circle 15 on Readers' Service card

Shield chamber for making electrically ultra-quiet measurements is used to enclose and test sensitive electronic circuitry on the workbench. Power is supplied to devices in the chamber by means of an isolation transformer unit with less than 0.005-pf interwinding capacitance and more than 10,000-megohm interwinding leakage resist-

ance. A complete box shield around the transformer's secondary winding is electrically continuous with the shield chamber. Electromagnetic shielding is said to be 40 db even at power line frequencies. Three sizes are available. (Topaz Transformer Products, Inc., 4995 Weeks Ave., San Diego 10, Calif.)

Circle 16 on Readers' Service card

Rubidium vapor frequency standard is based on optical pumping and transmission monitoring. It derives its stable frequency from the rubidium-87 ground state hyperfine transition of 6834.86 . . . Mcy/sec. Long-term stability is said to be 2 parts in 10^{10} and short term stability 3 parts in 10^{11} for a 1-sec sampling time. Absorption cells are manufactured to customer-specified time scale. Examples are Ephemeris Time (A.1) or the current standard frequency broadcast offset of -150×10^{-10} relative to A.1. Other cells for alternative frequencies can be supplied. Fine tuning over a range of 200 parts in 10^{10} affords time-scale flexibility. The instrument draws 110 watts and is designed for standby battery operation. Standard output frequencies are 5.0, 1.0, and 0.1 Mcy/sec, with others available on request. (Varian Associates, 611 Hansen Way, Palo Alto, Calif.)

Circle 17 on Readers' Service card

Reference current source is a portable battery-operated device for checking electrometer circuits. The source supplies 0.9 to 9 volts with seven current ranges from 10^{-6} to 10^{-12} amp. Accuracy is said to be ±1.5 percent. Power is supplied by seven mercury cells. (Gyra Electronics Corp., Washington and Elm Sts., La Grange, Ill.)

Circle 18 on Readers' Service card

Millivolt source, regulated by a Zener-diode, provides an output voltage adjustable in two ranges from 0 to 100 mv. Accuracy is said to be ±0.1 percent of full scale, and noise output less than 0.1 mv across the output terminals or from either output terminal to ground. (Westronics, Inc., 3605 McCart, Fort Worth 10, Tex.)

Circle 19 on Readers' Service card

Biomedical amplifier-transmitter is a three-channel instrument that makes possible remote monitoring of three bioelectrical signals by telemetry. The instrument amplifies, multiplexes, and transmits the signals over the standard FM frequency band. The signals are received up to 100 yards away by an

FM tuner and converted to a form suitable for recording or display. One channel has operating characteristics suitable for electrocardiograph, electromyograph, electroencephalograph, or galvanic skin response signals. The other two channels are designed for more slowly varying signals such as temperature, respiration, or blood pressure. (Litton Systems, Inc., Woodland Hills, Calif.)

Circle 20 on Readers' Service card

Spectrum analyzers, (Models MRFR 30-9 and MRFR 30-11) cover, respectively, any 300-cy/sec band and any 1260-cy/sec band between 5 cy/sec and 10 kcy/sec. In the former, the signal is applied to a bank of 100 filters, and in the latter to a bank of 420 filters. Filter outputs are sampled in sequence by a high-speed capacitive commutator, and the detected signal is amplified and displayed on an oscilloscope. A recorder which gives a permanent paper record of analysis can also be supplied. Sampling rate of the MRFR 30-9 is 30 scans per second, and resolution over the entire band is 8 cy/sec with a dynamic resolving range of 35 to 40 db. (Raytheon Co., 55 Chapel St., Newton 58, Mass.)

Circle 21 on Readers' Service card

Ultrasonic cell disrupter is said to break down cells effectively without inactivating the liberated enzymatic protein. The apparatus operates at a pretuned frequency of 20 kcy/sec. A magnetostrictive transducer generates ultrasonic energy in a 70-ml chamber. Either batch or continuous-flow models are available. The batch model will disrupt cells in quantities as small as 15 ml and as large as 70 ml. With the continuous-flow unit, as much as 1 lit. of cell slurry per hour may be processed. Both models incorporate a cooling system that maintains the fracturing chamber at 0°C. (Will Corp., P.O. Box 1050, Rochester 3, N.Y.)

Circle 22 on Readers' Service card

Infrared radiation collimator is an off-axis system that produces a beam of unobstructed radiation. It employs a plane reflecting mirror and an off-axis paraboloidal mirror both of which are aluminized and coated for high-reflectivity in the 0.25- to 16-μ region. Angular resolution is said to be 0.2 mil. A variety of sources can be positioned at the entrance aperture. An aperture wheel with seven apertures allows the flux density to be changed over a 1000

to 1 range. The collimator can be furnished with auxiliary radiation interrupting devices such as solenoid-actuated shutters or rotating sector disk choppers. (Barnes Engineering Co., 30 Commerce Rd., Stamford, Conn.)

Circle 23 on Readers' Service card

Perfusion apparatus is a system for the oxygenation, pumping, heating, and cooling of blood under "ideal" physiological and clinical conditions for extracorporeal flows during open-heart surgery. It can be used for operations within the normal blood-temperature range or under moderate or profound hypothermia flow conditions. The apparatus is basically a bubble oxygenator with a variable surface area. Instrumentation is provided for continuous monitoring of oxygen flow rate, pump pressure and vacuum, blood flow, *p*H, temperature, and pO_2. Pumping of the blood is accomplished by a pressure and vacuum cycle in a chamber containing a flap valve. Flows up to 4500 ml/min are available. Blood volume required for priming is 1700 ml. Overall dimensions are 45 by 38 in.; weight is approximately 400 lb. (Selas Corporation of America, Dresher, Pa.)

Circle 24 on Readers' Service card

High temperature hardness indentor is designed for use at temperatures as high as 3000°F. The indentor consists of a sapphire mounted in a molybdenum shank. It is available in sphero-conical and pyramidal shapes. The pyramidal model incorporates the standard Vickers 136-deg angle. (F. F. Gilmore & Co., 725 Boylston St., Boston 16, Mass.)

Circle 25 on Readers' Service card

Audiometer provides tone tests in nine steps from 250 to 8000 cy/sec, and it provides speech tests from a recording or live by means of a microphone. Signals can be presented to either or both ears, and a phone balance permits regulation of relative intensities. A monitor earphone with its own volume control is also provided. A threshold-level dial ranges from 10 to 100 db with markings in 1-db steps. The test tone can be interrupted manually or by automatic pulses; a masking signal of adjustable intensity is provided. (Otarion Listener Corp., Ossining, N.Y.)

Circle 26 on Readers' Service card

High-vacuum calculator of the slide-rule type is designed to permit calculation of pump or chamber size as well as time and pressure for high-vacuum systems. The calculator (over-all size, 8½ by 11 in.) consists of two slides held in place by a rigid vinyl casing. Each slide can be used to solve simple problems, and together, they are said to be capable of solving complex high-vacuum problems. (Consolidated Vacuum Corp., 1775 Mt. Read Blvd., Rochester 3, N.Y.)

Circle 27 on Readers' Service card

Gyro power source supplies a-c power for four two-phase gyro motors and records voltage and current for one phase of each motor. An eight-channel recorder simultaneously charts phase voltage with sensitivity to 0.01 percent per centimeter, and it charts the in-phase component of current consumed by that phase with sensitivity of 0.5 ma/cm. Output frequency is 800 cy/sec ±0.001 percent with frequencies between 300 and 5000 cy/sec available. Output voltage is 2 to 15 v ±0.1 percent. Regulation against line or load variations is ±1 percent. Maximum distortion is said to be 1 percent, with 0.1 percent available on special order. (Behlman Engineering, Burbank, Calif.)

Circle 28 on Readers' Service card

JOSHUA STERN
National Bureau of Standards, Washington, D.C.

ANNUAL BUYER'S GUIDE TO ADVERTISED PRODUCTS

On the pages that follow is a classified listing of all products advertised in SCIENCE since 13 October 1960. We have made every effort to make this Guide an aid to purchasers of new instruments and equipment for the laboratory. Under each classification is listed the name of the manufacturer and the issue and page where the advertisement appeared.

Cover positions are designated as follows:

IFC — Inside front cover
IBC — Inside back cover
BC — Back cover
1A — Page opposite inside front cover

By using this Buyer's Guide, it is possible to obtain immediately manufacturers' specifications on the newest laboratory tools. If, however, you do not find what you are looking for in this Guide, our Advertising Office will be happy to assist you further. Our market research department maintains extensive files on all types of laboratory equipment. Write to the address below, stating your requirements, and we will try to provide you with several sources.

SCIENCE Magazine
11 West 42 Street
New York 36, N.Y.

Accelerators, Electron

High Voltage Engineering Cor,
1960: 28 Oct. 1220
1961: 20 Jan., 162; 24 Feb., 548; 24 Mar., 846; 28 Apr., 1324; 19 May, 1556; 28 July, 248; 5 Aug., 438; 22 Sept., 800
Radiation Dynamics, Inc.
1960: 21 Oct., 1047
1961: 24 Mar., 812

Accelerators, Positive Ion

High Voltage Engineering Corp.
1961: 20 Jan., 162; 18 Aug., 438
Radiation Dynamics, Inc.
1960: 21 Oct., 1047

Air Pollution Test Equipment

Central Scientific Co.
1961: 24 Mar., 791

Amino Acid Analyzers

Beckman Instruments, Inc., Spinco Div.
1960: 14 Oct., IFC
1961: 24 Feb., IFC; 12 May, IFC; 14 July, IFC; 11 Aug., IFC
Phoenix Precision Instrument Co.
1960: 21 Oct., 1180; 11 Nov., 1432; 2 Dec., 1690
1961: 17 Feb., 536; 24 Mar., 816; 21 Apr., 1292; 19 May, 1656; 16 June, 1964; 18 Aug., 502
Research Specialties Co.
1961: 3 Mar., 656
Technician Chromatography Corp.
1961: 20 Jan., 221; 21 July, 226

Amplifiers

American Electronic Laboratories, Inc.
1961: 17 Feb., 513
Argonaut Associates
1961: 20 Jan., 214
Baird-Atomic, Inc.
1960: 2 Dec., 1613
1961: 20 Jan., 139
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 23 Dec., 1900
1961: 17 Mar., 768; 9 June, 1836
Decker Corp.
1961: 24 Mar., 787
Philbrick, George A., Researches, Inc.
1961: 18 Aug., 478
Sanborn Co.
1961: 17 Feb., 414; 29 Sept., IFC

Animal Food

Staley, A. E., Mfg. Co.
1961: 27 Jan., 247; 24 Feb., 589; 21 Apr., 1288; 19 May, 1658; 16 June, 1938; 14 July, 115; 11 Aug., 397; 29 Sept., 909

Animals, Laboratory

Charles River Breeding Laboratories
1960: 7 Oct., 974
Sprague-Dawley, Inc.
1960: 2 Dec., 1714; 9 Dec., 1846
1961: 13 Jan., 111

Atomic Absorption Photometers

Engis Equipment Co.
1960: 21 Oct., 1173
1961: 7 July, 63

Balances, Analytical

Ainsworth, Wm., & Sons, Inc.
1961: 20 Jan., 201; 24 Mar., 911; 19 May, 1635
Brinkmann Instruments, Inc.
1960: 7 Oct., 917; 21 Oct., 1119
1961: 17 Feb., 419
Burrell Corp.
1961: 22 Sept., 881
Exact Weight Scale Co.
1961: 21 July, 223
Harshaw Scientific Co.
1960: 18 Nov., 1503
Mettler Instrument Corp.
1960: 21 Oct., 1081; 2 Dec., 1612
1961: 24 Mar., 931; 21 Apr., 1188; 21 July, 152
Sauter, August, of New York, Inc.
1960: 21 Oct., 1181
1961: 17 Feb., 530; 21 Apr., 1288
Scientific Products, Div. of American Hospital Supply Corp.
1961: 22 Sept., 776
Stoelting, C. H., Co.
1960: 21 Oct., 1203
1961: 6 Jan., 55; 24 Mar., 931; 22 Sept., 863
Torsion Balance Co.
1960: 21 Oct., 1065; 11 Nov., 1343
1961: 24 Mar., 833; 21 Apr., 1163; 22 Sept., 755
Will Corp.
1960: 11 Nov., 1411
1961: 21 Apr., 1275

Balances, Analytical, Micro

Mettler Instrument Corp.
1961: 20 Jan., 155
Sauter, August, of New York, Inc.
1960: 2 Dec., 1692
1961: 24 Mar., 902

Balances, Animal

Aloe Scientific
1961: 16 June, 1963; 21 July, 229
Exact Weight Scale Co.
1960: 21 Oct., 1161; 2 Dec., 1674
1961: 17 Feb., 523; 19 May, 1616; 21 July, 223; 22 Sept., 891

Balances, Micro Torque

Brinkmann Instruments, Inc.
1960: 28 Oct., 1263
1961: 24 Mar., 914; 22 Sept., 859

Balances, Prescription

Harshaw Scientific Co.
1961: 24 Mar., 952; 21 Apr., 1284
Torsion Balance Co.
1961: 20 Jan., 137; 24 Mar., 833; 21 Apr., 1163; 19 May, 1509; 21 July, 143

Balances, Trip

Ohaus Scale Corp.
1961: 22 Sept., 894

Balances, Triple Beam

Ohaus Scale Corp.
1961: 22 Sept., 894
Welch, W. M., Scientific Co.
1960: 28 Oct., 1267; 4 Nov., 1321
1961: 3 Feb., 341; 5 May, 1433

Borers, Cork

Bottles, Plastic

Burettes, Automatic

Burettes, Micro

Greiner, Emil, Co.
1960: 21 Oct., 1180

Burettes, Multiple Column

Buchler Instruments, Inc.
1960: 21 Oct., 1183; 2 Dec., 1600

Burners, Glass Blowing

Bethlehem Apparatus Co., Inc.
1960: 11 Nov., 1422

Burners, Laboratory

LABASCO
1961: 24 Mar., 819

Cages, Dog and Primate

Harford Metal Products
1961: 6 Oct., 1022
Kirschner Manufacturing Co.
1960: 21 Oct., 1199; 11 Nov., 1419; 2 Dec., 1691
1961: 21 July, 219
Porter Mathews Co., Inc.
1961: 7 July, 8

Cages, Dog and Primate, Plastic

Aloe Scientific
1961: 21 July, 229
Kirschner Manufacturing Co.
1960: 21 Oct., 1199; 11 Nov., 1419; 2 Dec., 1691
1961: 20 Jan., 207; 31 Mar., 1025; 19 May, 1655; 16 June, 1936; 21 July, 219; 22 Sept., 871

Cages, Metabolism

Delmar Scientific Laboratories
1961: 17 Feb., 534; 21 Apr., 1278

Cages, Small Animal, Metal

Aloe Scientific
1961: 16 June, 1963
Harford Metal Products
1961: 6 Oct., 1022
Porter Mathews Co., Inc.
1961: 7 July, 8
Will Corp.
1961: 16 June, 1933

Cages, Small Animal, Plastic

Aloe Scientific
1960: 11 Nov., 1417; 2 Dec., 1709
1961: 16 June, 1963; 21 July, 229
Keystone Plastics Co.
1961: 17 Feb., 494; 24 Mar., 898; 21 Apr., 1267; 19 May, 1624
Labline, Inc.
1961: 20 Jan., 233; 17 Feb., 504; 21 Apr., 1287; 19 May, 1631; 15 Sept., 756
Maryland Plastics, Inc.
1960: 21 Oct., 1087
1961: 17 Feb., 535; 24 Mar., 960; 21 Apr., 1302; 19 May, 1514; 22 Sept., 768

Calorimeters

Parr Instrument Co.
1960: 21 Oct., 1184
1961: 20 Jan., 206; 19 May, 1610

Capacitance Measuring Equipment

Decker Corp.
1961: 24 Mar., 786

Carbon Hydrogen Analyzers

Coleman Instruments, Inc.
1961: 17 Feb., 422; 19 May, 1546

Carbon Sulphur Analyzers

Lindberg Engineering Co.
1961: 19 May, 1618

Cardiotachometers

Gilford Instrument Laboratories, Inc.
1961: 22 Sept., 879

Carts, Laboratory

Harshaw Chemical Co.
1961: 26 May, 1720

Catalogs, Laboratory Equipment

Cole-Parmer Instrument & Equipment Co.
1961: 19 May, 1628; 16 June, 1951
Labline, Inc.
1961: 24 Mar., 902; 22 Sept., 850
LaPine Scientific Co.
1961: 22 Sept., 876
Matheson Coleman & Bell
1961: 16 June, 1874; 21 July, 200
New York Laboratory Supply Co., Inc.
1961: 3 Feb., 336
Sargent, E. H., & Co.
1961: 21 Apr., 1169; 19 May, 1543; 18 Aug., 421
Thomas, Arthur H., Co.
1961: 13 Jan., BC; 24 Mar., BC
Will Corp.
1961: 19 May, 1644

Cells, Absorption

Beckman Instruments, Inc., Scientific and Process Instruments Div.
1961: 26 May, 1672
Klett Manufacturing Co.
1960: 7 Oct., 973; 14 Oct., 1022; 21 Oct., 1152; 28 Oct., 1265; 4 Nov., 1328; 11 Nov., 1427; 18 Nov., 1505; 2 Dec., 1703; 9 Dec., 1779; 16 Dec., 1848; 23 Dec., 1901; 30 Dec., 1946
1961: 6 Jan., 51; 13 Jan., 117; 20 Jan., 215; 27 Jan., 287; 3 Feb., 338; 10 Feb., 390; 17 Feb., 532; 24 Feb., 596; 3 Mar., 652; 10 Mar., 715; 17 Mar., 773; 24 Mar., 920; 31 Mar., 1025; 7 Apr., 1088; 14 Apr., 1141; 21 Apr., 1294; 28 Apr., 1371; 12 May, 1497; 19 May, 1637; 26 May, 1721; 2 June, 1776; 9 June, 1839; 16 June, 1949; 23 June, 2023; 30 June, 2073; 7 July, 64; 14 July, 116; 21 July, 289; 4 Aug. 347; 11 Aug., 398; 18 Aug., 507; 1 Sept., 625; 15 Sept., 745; 22 Sept., 852; 29 Sept., 953

Cells, Spectrophotometer

Brinkmann Instruments, Inc.
1961: 3 Feb., 340

Centrifuges, Analytical (Student)

Clay-Adams
1961: 20 Jan., 161; 3 Mar., 607
International Equipment Co.
1961: 24 Mar., 826

Centrifuges, Continuous Flow

Lourdes Instrument Corp.
1961: 17 Feb., 499; 21 Apr., 1291
Sorvall, Ivan, Inc.
1960: 11 Nov., 1067; 2 Dec., 1580, 1581
1961: 17 Feb., 402; 24 Mar., 800

Centrifuges, General Purpose

Custom Scientific Instruments, Inc.
1961: 18 Aug., 497
International Equipment Co.
1960: 21 Oct., 1049
1961: 6 Jan., 10; 20 Jan., 145; 24 Mar., 827; 28 July, 1A
Lourdes Instrument Corp.
1960: 7 Oct., 969; 21 Oct., 1155
1961: 17 Feb., 499; 21 Apr., 1291
Scientific Glass Apparatus Co., Inc.
1960: 21 Oct., 1059
Sorvall, Ivan, Inc.
1960: 21 Oct., 1066, 1067; 2 Dec., 1580
1961: 17 Feb., 402; 24 Mar., 800

Centrifuges, Hematocrit

Clay-Adams
1961: 17 Feb., 437
International Equipment Co.
1960: 11 Nov., 1340
1961: 3 Mar., IBC; 24 Mar., 826; 8 Sept., 632

Centrifuges, Micro

Beckman Instruments, Inc., Spinco Div.
1961: 23 June, IFC; 8 Sept., IFC
International Equipment Co.
1961: 8 Sept., 632

Centrifuges, Refrigerated

International Equipment Co.
1960: 21 Oct., 1049; 11 Nov., 1341
1961: 17 Feb., 428; 24 Mar., 827; 14 Apr., 1099; 12 May, 1449; 9 June, 1791; 23 June, 1977; 28 July, 1A; 25 Aug., 523; 29 Sept., 907
Lourdes Instrument Corp.
1960: 21 Oct., 1155; 11 Nov., 1431
1961: 17 Feb., 499; 21 Apr., 1291; 22 Sept., 893
Sorvall, Ivan, Inc.
1960: 21 Oct., 1067; 2 Dec., 1581
1961: 20 Jan., 142; 17 Feb., 402; 24 Mar., 801; 19 May, 1606; 16 June, 1866

Centrifuges, Super Speed

International Equipment Co.
1960: 11 Nov., 1341
Lourdes Instrument Corp.
1960: 21 Oct., 1155; 11 Nov., 1431
1961: 22 Sept., 893
Sorvall, Ivan, Inc.
1960: 21 Oct., 1067
1961: 17 Feb., 402; 24 Mar., 801; 19 May, 1606

Centrifuges, Ultra Speed

Beckman Instruments, Inc., Spinco Div.
1960: 28 Oct., IFC; 9 Dec., IFC; 23 Dec., IFC
1961: 13 Jan., IFC; 27 Jan., IFC; 10 Mar., IFC; 14 Apr., IFC; 9 June, IFC; 28 July, IFC; 22 Sept., IFC

Centrifuges, Vacuum

Lourdes Instrument Corp.
1961: 24 Mar., 939; 19 May, 1657

Charts, Biological

Welch, W. M., Scientific Co.
1960: 2 Dec., 1685
1961: 3 Mar., 652; 1 Sept., 623

Charts, Periodic Table

Central Scientific Co.
1961: 21 Apr., 1263

Chemical Analyzers, Automatic

Research Specialties Co.
1961: 3 Mar., 656
Technicon Chromatography Corp.
1961: 20 Jan., 221; 17 Feb., 529; 24 Mar., 905; 21 Apr., 1305; 16 June, 1961; 22 Sept., 895

Chemicals, Biological

Applied Science Laboratories., Inc.
1961: 22 Sept., 892
Borden Chemical Co.
1961: 24 Mar., 954; 28 Apr., 1376; 16 June, 1958; 8 Sept., 682
Colorado Serum Co.
1961: 24 Mar., 941; 21 Apr., 1263; 11 Aug., 400
Eastern Chemical Corp.
1960: 7 Oct., 971
1961: 6 Oct., 1022
General Biochemicals
1961: 20 Jan., 156; 17 Feb., 417; 24 Mar., 837; 21 Apr., 1182; 19 May, 1554; 16 June, 1881; 21 July, 141
Hyland Laboratories
1961: 19 May, 1639; 16 June, 1948; 21 July, 225; 18 Aug., 482
Nutritional Biochemicals Corp.
1960: 14 Oct., 1A; 28 Oct., 1A; 11 Nov., 1A; 25 Nov., 1A; 2 Dec., 1A; 23 Dec., 1A
1961: 6 Jan., 1A; 20 Jan., 1A; 3 Feb., 1A; 17 Feb., 1A; 3 Mar., 1A; 17 Mar., 1A; 31 Mar., 1A; 14 Apr., 1A; 28 Apr., 1A; 12 May, 1A; 26 May, 1A; 9 June, 1A; 23 June, 1A; 7 July, 3; 21 July, 1A; 4 Aug., 1A; 18 Aug., 1A; 1 Sept., 1A; 15 Sept., 1A; 29 Sept. 1A
Pabst Laboratories
1961: 20 Jan., 212; 17 Feb., 495; 24 Mar., 899
Pfanstiehl Laboratories, Inc.
1961: 24 Mar., 936
Schwarz BioResearch, Inc.
1960: 21 Oct., 1169; 4 Nov., 1327; 2 Dec., 1695
1961: 6 Jan., 57; 20 Jan., 152; 3 Feb., 337; 17 Feb., 435; 3 Mar., 604; 17 Mar., 774; 7 Apr., 1041; 21 Apr., 1161; 5 May, 1390; 26 May, 1718; 16 June, 1856; 21 July, 235; 4 Aug., 301; 18 Aug., 411; 8 Sept., 638; 15 Sept., 697; 22 Sept., 777
Sigma Chemical Co.
1960: 21 Oct., 1205; 11 Nov., 1426
1961: 6 Jan., 51; 20 Jan., 227; 3 Mar., 653; 31 Mar., 1025; 21 Apr., 1285; 19 May, 1618; 16 June, 1946; 21 July, 211; 22 Sept., 859
Winthrop Laboratories
1960: 25 Nov., 1566
1961: 10 Feb., 390; 17 Mar., 773; 15 Sept., 741

Worthington Biochemical Corp.
1960: 4 Nov., 1322; 2 Dec., 1710
1961: 24 Feb., 595; 24 Mar., 938; 28 Apr., 1372; 26 May, 1674; 16 June, 1966; 21 July, 228; 18 Aug., 510; 22 Sept., 860

Chemicals, Organic

Allied Chemical, General Chemical Div.
1961: 24 Mar., 1A
Baker, J. T., Chemical Co.
1960: 21 Oct., 1085
Eastern Chemical Corp.
1960: 7 Oct., 971
1961: 6 Oct., 1022
Matheson Coleman & Bell
1960: 21 Oct., 1174
1961: 22 Sept., 764

Chemicals, Radiation

ChemTrac Corp.
1961: 21 July, 204; 22 Sept., 848
Isomet Corp.
1961: 22 Sept., 889
Isotopes Specialties Co.
1960: 21 Oct., 1163; 2 Dec., 1717
New England Nuclear Corp.
1960: 7 Oct., 972; 21 Oct., 1151; 4 Nov., 1329; 11 Nov., 1424; 9 Dec., 1779
1961: 6 Jan., 48; 20 Jan., 235; 3 Feb., 340; 17 Feb., 491; 24 Mar., 913; 14 Apr., 1141; 28 Apr., 1374; 28 Apr., 1377; 5 May, 1436; 26 May, 1721; 2 June, 1779; 16 June, 1955; 30 June, 2073; 14 July, 116; 28 July, 289; 11 Aug., 398; 1 Sept., 681; 22 Sept., 1A; 29 Sept., 953; 6 Oct., 1021
Nuclear-Chicago Corp.
1961: 10 Mar., BC
Oak Ridge National Laboratory
1960: 21 Oct., 1164; 4 Nov., 1325; 2 Dec., 1678
1961: 20 Jan., 225; 17 Feb., 522; 24 Mar., 916; 21 Apr., 1260; 19 May, 1623; 16 June, 1962; 14 July, 115; 18 Aug., 570; 15 Sept., 742
Picker X-Ray Corp.
1961: 22 Sept., 790
Pilot Chemicals Inc.
1960: 21 Oct., 1195; 2 Dec., 1685
1961: 20 Jan., 230; 19 May, 1646
Radiochemical Centre
1961: 6 Jan., 55; 3 Mar., 655; 28 Apr., 1371; 23 June, 2027; 21 July, 212; 15 Sept., 745
Schwarz BioResearch, Inc.
1961: 3 Feb., 337; 17 Mar., 774; 26 May, 1718; 16 June, 1856
Tracerlab, Inc.
1961: 9 June, 1837; 11 Aug., 401

Chemicals, Reagents

Allied Chemical Corp., General Chemical Div.
1960: 11 Nov., 1412; 2 Dec., 1676
1961: 24 Mar., 783; 19 May, 1611, 1613, 1615; 22 Sept., 773
Baker, J. T., Chemical Co.
1960: 21 Oct., 1085; 11 Nov., 1418; 2 Dec., 1589
1961: 20 Jan., 134; 17 Feb., 510; 24 Mar., 795; 19 May, 1521; 16 June, 1934
Burrell Corp.
1961: 28 Apr., 1373
Dupont, E. I., de Nemours & Co., Inc.
1961: 17 Feb., 528; 24 Mar., 957; 21 Apr., 1280; 19 May, 1632; 16 June, 1940; 21 July 208; 18 Aug., 490; 22 Sept., 846; 29 Sept., 956
Eastern Chemical Corp.
1961: 6 Oct., 1022
Fisher Scientific Co.
1961: 24 Mar., 843; 7 Apr., 1039; 5 May, 1387; 9 June, 1789
Hyland Laboratories
1961: 21 Apr., 1272; 16 June, 1948; 21 July, 225
Mallinckrodt Chemical Works
1960: 2 Dec., 1610, 1611
Matheson Coleman & Bell
1960: 21 Oct., 1174; 2 Dec., 1700
1961: 17 Feb., 536; 24 Mar., 807; 19 May, 1545; 16 June, 1874; 21 July, 200
Research Specialties Co.
1961: 7 Apr., 1086

Chromatogram Scanners

Atomic Accessories, Inc.
1961: 16 June, 1852
Forro Scientific Co.
1961: 17 Feb., 505
National Instrument Laboratories, Inc.
1961: 21 July, 228
Photovolt Corp.
1961: 17 Feb., 509; 24 Mar., 901; 21 Apr., 1267; 21 July, 205
Picker X-Ray Corp.
1961: 21 Apr., 1156
Vanguard Instrument Co.
1961: 17 Feb., 425; 21 Apr., 1168; 19 May, 1528; 16 June, 1864; 1 Sept., IBC

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Chromatographs, Column Packing

Johns-Manville
1961: 21 Apr., 1166; 19 May, 1512; 16 June, 1859; 22 Sept., 796

Chromatographs, Gas

Barber-Colman Co., Industrial Instruments Div.
1960: 21 Oct., 1960; 16 Dec., 1A
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 2 Dec., 1604
1961: 10 Feb., 353; 24 Feb., 546; 14 Apr., 1102; 16 June, 1877; 18 Aug., 505; 29 Sept., 911
Burrell Corp.
1961: 24 Feb., 592; 24 Mar., 932
Central Scientific Co.
1960: 7 Oct., 973; 2 Dec., 1717
1961: 10 Mar., 716
Fisher Scientific Co.
1961: 24 Mar., 843
F & M Scientific Corp.
1960: 21 Oct., 1058; 11 Nov., 1346; 2 Dec., 1603
1961: 20 Jan., 143; 17 Feb., 433; 24 Mar., 802; 21 Apr., 1160; 19 May, 1544; 16 June, 1848; 21 July, 130; 18 Aug., 416; 22 Sept., 770
Gow-Mac Instrument Co.
1961: 21 July, 202
Nester & Faust
1961: 22 Sept., 866
Perkin-Elmer Corp.
1960: 2 Dec., 1576
1961: 27 Jan., 244
Precision Scientific Co.
1961: 19 May, 1531; 16 June, 1871; 21 July, 151; 18 Aug., 427
Research Specialties Co.
1960: 2 Dec., 1718; 30 Dec., 1948
1961: 20 Jan., 234
Scientific Glass Apparatus Co., Inc.
1961: 21 Apr., 1304; 19 May, 1506
Standard Scientific Supply Corp.
1961: 18 Aug., 480

Chromatographs, Liquid

Brinkmann Instruments, Inc.
1960: 25 Nov., 1565
1961: 20 Jan., 219; 19 May, 1532
Buchler Instruments, Inc.
1961: 21 July, 219; 22 Sept., 762; 6 Oct., 1018
Gilford Instrument Laboratories, Inc.
1961: 6 Oct., 1022
Gilson Medical Electronics
1961: 6 Jan., 50
LKB Instruments, Inc.
1960: 16 Dec., 1791
Technicon Chromatography Corp.
1960: 21 Oct., 1181

Chromatographs, Paper Strip

Gilson Medical Electronics
1961: 7 Apr., 1036
Kensington Scientific Corp.
1960: 28 Oct., 1265; 2 Dec., 1713; 30 Dec., IBC
1961: 20 Jan., 229; 17 Feb., 491; 24 Mar., 913; 21 Apr., 1281; 19 May, 1633; 16 June, 1949; 21 July, 209
LKB Instruments, Inc.
1961: 21 Apr., 1158
National Instrument Laboratories, Inc.
1961: 21 July, 228

Colorimeters, Photoelectric Reflectional

Zeiss, Carl, Inc.
1961: 8 Sept., 640

Combustion Analyzers

Coleman Instruments, Inc.
1961: 17 Feb., 422; 17 Mar., 726; 19 May, 1546
Lindberg Engineering Co.
1961: 17 Feb., 529

Comparators, Optical

Nikon, Inc.
1961: 16 June, 1857; 21 July 150; 22 Sept., 758

Computers, Analog

Philbrick, George A., Researches, Inc.
1961: 17 Mar., 772

Computers. Digital

Bendix Corp.
1960: 21 Oct., 1068; 11 Nov., 1353
1961: 3 Feb., IBC
Burroughs Corp.
1961: 24 Mar., 792
Mnemotron Corp.
1961: 2 June, 1734; 30 June, 2034; 22 Sept., 795
Royal McBee Corp.
1961: 19 May, 1511; 16 June, 1867; 7 July, 11

Conductivity Cells

Industrial Instruments, Inc.
1960: 2 Dec., 1716
1961: 20 Jan., 198

Conductivity Meters

Industrial Instruments, Inc.
1960: 21 Oct., 1192; 2 Dec., 1716
1961: 20 Jan., 198; 24 Mar., 958; 19 May, 1650; 16 June, 1962; 18 Aug., 508
Leeds & Northrup Co.
1960: 21 Oct., 1040
London Co.
1961: 21 Apr., 1178

Controllers, Electronic

Smith, Arthur F., Inc.
1960: 7 Oct., 968; 2 Dec., 1680

Counters, Bacteriological

American Optical Co.
1961: 3 Mar., BC; 21 July, 153
New Brunswick Scientific Co., Inc.
1961: 17 Feb., 517; 26 May, 1721; 29 Sept., 953

Counters, Blood Cell
See Blood cell counters

Counters, Drop
See Drop counters

Counters, Flow Radiation
See Flow counters, radiation

Counters, Liquid Scintillation, Automatic

Baird-Atomic, Inc.
1961: 3 Mar., 608; 17 Mar., 789; 21 Apr., 1155; 19 May, 1539

Counters, Radiation, Automatic Sample Changing

Baird-Atomic, Inc.
1961: 20 Jan., 139; 1 Sept., 584
Packard Instrument Co., Inc.
1960: 14 Oct., 990; 11 Nov., 1368
1961: 6 Jan., 12; 24 Mar., 794; 14 Apr., 1104; 21 Apr., 1165; 23 June, 1980; 7 July, 14; 5 Aug., 304; 1 Sept., 586
Technical Associates
1961: 24 Mar., 822

Counters, Whole Body

Packard Instrument Co., Inc.
1961: 6 Jan., 12; 3 Feb., 302; 17 Feb., 442; 3 Mar., 612; 31 Mar., 789; 21 Apr., 1165; 12 May, 1454; 9 June, 1794; 21 July, 160; 8 Aug., 440; 15 Sept., 702
Nuclear-Chicago Corp.
1961: 7 Apr., BC; 2 June, BC; 30 June, BC; 28 July, BC; 25 Aug., BC

Counters and Scalers, Gamma Radiation

Atomic Accessories Inc.
1960: 21 Oct., 1202
Baird-Atomics, Inc.
1961: 16 June, 1853; 22 Sept., 799
Hamner Electronics Co., Inc.
1961: 22 Sept., 892
Lionel Electronic Laboratories (formerly Anton Electronic Laboratories, Inc.)
1961: 20 Jan., 205; 16 June, 1953

Nuclear-Chicago Corp.
1961: 19 May, BC
Nuclear Measurements Corp.
1961: 24 Mar., 916; 19 May, 1653
Packard Instrument Co., Inc.
1960: 14 Oct., 990; 25 Nov., 1522
1961: 6 Jan., 12; 3 Feb., 302; 24 Mar., 794; 14 Apr., 1104; 21 Apr., 1165; 26 May, 1678: 7 July, 14
Picker X-Ray Corp.
1960: 18 Nov., 1447
1961: 24 Mar., 828; 16 June, 1868; 21 July, 154; 18 Aug., 435
Radiation Counter Laboratories, Inc.
1961: 16 June, 1845
Radiation Equipment & Accessories Corp.
1961: 24 Mar., 956
Radiation Instrument Development Laboratory, Inc.
1960: 21 Oct., 1042
Technical Associates
1960: 21 Oct., 1036
1961: 19 May, 1552
Technical Measurement Corp.
1961: 21 Apr., 1194; 12 May, 1452; 16 June, 1882
Tracerlab, Inc.
1960: 21 Oct., 1080
1961: 31 Mar., IFC
Victoreen Instrument Co.
1960: 21 Oct., 1079

Counters and Scalers, Low-Level Radiation

Atomic Accessories Inc.
1960: 2 Dec., 1673
Baird-Atomic, Inc.
1961: 16 June, 1853
General Measurements
1961: 22 Sept., 885
Hamner Electronics Co., Inc.
1961: 22 Sept., 892
Isotopes, Inc.
1960: 21 Oct., 1186
Lionel Electronic Laboratories (formerly Anton Electronic Laboratories, Inc.)
1961: 24 Mar., 955; 16 June, 1953
Nuclear-Chicago Corp.
1961: 19 May, BC
Packard Instrument Co., Inc.
1961: 6 Jan., 12; 3 Feb., 302; 21 Apr., 1165
Picker X-Ray Corp.
1960: 18 Nov., 1A; 2 Dec., 1595
1961: 16 June, 1868; 21 July, 154; 18 Aug., 435
Radiation Counter Laboratories, Inc.
1961: 16 June, 1845
Radiation Equipment & Accessories Corp.
1961: 24 Mar., 956
Radiation Instrument Development Laboratory, Inc.
1960: 21 Oct., 1042
Sharp Laboratories, Inc.
1960: 21 Oct., 1185
Technical Associates.
1960: 21 Oct., 1036
1961: 19 May, 1552
Tracerlab, Inc.
1960: 21 Oct., 1080
1961: 31 Mar., IFC; 19 May, 1524
Victoreen Instrument Co.
1960: 21 Oct., 1079

Crucibles, Porcelain

Coors Porcelain Co.
1960: 21 Oct., 1199
1961: 24 Mar., 936

Crystal Growing Kits

Edmund Scientific Co.
1961: 24 Mar., 829

Crystals, Infrared

Isomet Corp.
1960: 2 Dec., 1699

Crystals, Optical

Harshaw Chemical Co.
1960: 7 Oct., 965
1961: 24 Feb., 591; 14 Apr., 1139; 16 June, 1933

Crystals, Scintillation

Harshaw Chemical Co.
1960: 7 Oct., 965; 9 Dec., 1775
1961: 24 Feb., 591; 14 Apr., 1139; 16 June, 1933; 25 Aug., 525

Culture Apparatus, Bacteriological

American Sterilizer Co.
1960: 11 Nov., 1351
1961: 20 Jan., 129; 24 Mar., 839; 22 Sept., 763
Bellco Glass, Inc.
1960: 18 Nov., 504
Delmar Scientific Laboratories
1961: 17 Feb., 534; 21 Apr., 1278
Kontes Glass Co.
1961: 21 July, 214

Culture Flasks

Bellco Glass, Inc.
1960: 4 Nov., 1321; 18 Nov., 1507
1961: 21 Apr., 1299
Kontes Glass Co.
1961: 21 July, 214

Culture Media

Difco Laboratories
1960: 21 Oct., 1167; 11 Nov., 1409; 2 Dec., 1691
1961: 20 Jan., 215; 17 Feb., 503; 24 Mar., 901; 21 Apr., 1294; 19 May, 1629; 16 June, 1945; 21 July, 219; 18 Aug., 493; 22 Sept., 863
Hyland Laboratories
1960: 21 Oct., 1153; 11 Nov., 1429; 23 Dec., 1899
1961: 20 Jan., 218; 17 Feb., 524; 24 Mar., 924; 22 Sept., 878

Culture Tube Closures

Bellco Glass, Inc.
1960: 4 Nov., 1321; 18 Nov., 1507; 2 Dec., 1713
1961: 20 Jan., 236; 3 Mar., 655; 24 Mar., 944; 14 Apr., 1140; 29 Sept., 954
Bio-Tech, Inc.
1961: 6 Oct., 1020

Demonstration Equipment, Nuclear

Lionel Electronic Laboratories
1961: 18 Aug., 418; 22 Sept., 765
Nuclear-Chicago Corp.
1961: 8 Sept., 635
Picker X-Ray Corp.
1960: 18 Nov., 1A
1961: 17 Feb., 413

Demonstration Equipment, Physics

Central Scientific Co.
1960: 16 Dec., 1847
1961: 20 Jan., 147; 7 Apr., 1088
Macalaster Bicknell Corp.
1961: 6 Oct., 1019

Densitometers, Micro

National Instrument Laboratories, Inc.
1960: 21 Oct., 1120
Photovolt Corp.
1960: 11 Nov., 1419
Welch, W. M., Scientific Co., Inc.
1960: 7 Oct., 967

Desalters

Kensington Scientific Corp.
1960: 28 Oct., 1265; 11 Nov., 1428
1961: 21 July, 209; 22 Sept., 879
Research Specialties Co.
1961: 30 June, 2072

Desiccators

Ace Glass, Inc.
1960: 21 Oct., 1189
Precision Scientific Co.
1961: 21 July, 151

Detectors, Gas Density

Gow-Mac Instrument Co.
1961: 21 July, 202

Detectors, Infrared

Williamson Development Co., Inc.
1961: 20 Jan., 232

Detectors, Radiation

Lionel Electronic Laboratories
1961: 17 Feb., 519

Dewar Flasks

Hofman Laboratories, Inc.
1961: 16 June, 1954

Diamond Knives

Du Pont, E. I., de Nemours & Co., Inc.
1961: 18 Aug., 511

Diffraction Gratings

Bausch & Lomb Optical Co.
1961: 8 Sept., 642

Diluters, Automatic

National Instrument Co., Inc.
1961: 18 Aug., 493

Disintegrators, Ultrasonic

Brinkmann Instruments, Inc.
1960: 11 Nov., 1435
1961: 20 Jan., 208
Heat Systems Co.
1961: 19 May, 1640; 22 Sept., 884
Instrumentation Associates
1961: 24 Mar., 920; 28 Apr., 1374
Scientific Glass Apparatus Co., Inc.
1961: 18 Aug., 500
Will Corp.
1961: 18 Aug., 511; 22 Sept., 882

Electron Spin Resonance Equipment

Ridgefield Instrument Group
1961: 24 Mar., 935

Electrophoresis, Disc

Canal Industrial Corp.
1961: 30 June, 2074; 14 July, 114; 25 Aug., 571

Electrophoresis, Liquid

Beckman Instruments, Inc., Spinco Div.
1960: 11 Nov., IFC; 25 Nov., IFC
1961: 10 Feb., IFC; 25 Aug., IFC
Brinkmann Instruments, Inc.
1961: 19 May, 1532
E-C Apparatus Co.
1960: 21 Oct., 1167
1961: 20 Jan., 217
Fisher Scientific Co.
1961: 12 May, 1493; 25 Aug., 569
Gilson Medical Electronics
1961: 1 Sept., 622
JKM Instrument Co., Inc.
1961: 19 May, 1525
Kern Co.
1960: 7 Oct., 964
LKB Instruments, Inc.
1961: 21 Apr., 1158
National Instrument Laboratories, Inc.
1960: 21 Oct., 1121
Servonuclear Corp.
1961: 26 May, 1726

Electrophoresis, Paper

Beckman Instruments, Inc., Spinco Div.
1961: 26 May, IFC
Buchler Instruments, Inc.
1961: 5 May, 1434; 22 Sept., 762
JKM Instrument Co., Inc.
1961: 22 Sept., 889
Photovolt Corp.
1961: 16 June, 1955
Thomas, Arthur H., Co.
1961: 22 Sept., BC

Electrophoresis, Paper Strip Scanners

Gilson Medical Electronics
1961: 7 Apr., 1036
Photovolt Corp.
1961: 20 Jan., 207; 17 Feb., 509; 19 May, 1641; 16 June, 1955
Servonuclear Corp.
1960: 21 Oct., 1156

Electrophoresis, Solid Media

Buchler Instruments, Inc.
1961: 3 May, 1434; 16 June, 1950
Canal Industrial Corp.
1961: 31 Mar., 974; 21 Apr., 1150
National Instruments Laboratories, Inc.
1961: 21 July, 228

Electroplating Analyzers

Greiner, Emil, Co.
1961: 21 Apr., 1264

Environmental Chambers

Electric Hotpack Co., Inc.
1960: 11 Nov., 1435
1961: 17 Feb., 525
Lehigh Valley Electronics
1961: 22 Sept., 868

Evaporators, Flash

Buchler Instruments, Inc.
1960: 2 Dec., 1600

Evaporators, Rotary

Buchler Instruments, Inc.
1960: 2 Dec., 1600
1961: 19 May, 1538
Nester & Faust
1961: 21 Apr., 1276; 21 July, 210
VirTis Co.
1961: 16 June, 1872

Evaporators, Vacuum Coating

Mikros Inc.
1961: 22 Sept., 851
National Research Corp.
1961: 18 Aug., 481

Exposure Meters, Photomicrographic
See Photomicrographic exposure meters

Extractors, Fat

Delmar Scientific Laboratories
1961: 17 Feb., 534; 21 Apr., 1278

Feed, Animal
See Animal food

Fermentation Equipment

New Brunswick Scientific Co., Inc.
1960: 21 Oct., 1163
1961: 3 Feb., 335; 9 June, 1837; 6 Oct., 1015

Filiments, Wire

Gow-Mac Instrument Co.
1961: 17 Feb., 512

Film, Transparencies

Polaroid Corp.
1961: 19 May, 1549

Filter Funnels

Ace Glass, Inc.
1961: 17 Feb., 527

Filter, Gel

Pharmacia
1961: 3 Feb., 298; 24 Feb., IBC; 17 Mar., 728; 14 Apr., IBC; 8 Sept., 636

Filter Papers

Eaton-Dikeman Co.
1960: 21 Oct., 1178; 2 Dec., 1696
1961: 17 Feb., 514; 24 Mar., 908; 21 Apr., 1296; 19 May, 1551; 21 July, 131; 22 Sept., 759
Schleicher, Carl, & Schuell Co.
1960: 21 Oct., 1154
1961: 21 Apr., 1262; 12 May, 1496
Reeve Angel
1961: 20 Jan., 127; 17 Feb., 436; 19 May, 1507; 21 July, 147; 22 Sept., 754

Filters, Bacteriological

Custom Scientific Instruments, Inc.
1961: 16 June, 1862; 18 Aug., 497
Millipore Filter Corp.
1961: 18 Aug., 502

Filters, Interference

Baird-Atomic, Inc.
1960: 21 Oct., 1151
1961: 20 Jan., 203; 24 Mar., 907; 21 Apr., 1172; 5 May, 1389; 19 May, 1527; 15 Sept., 698
Bausch & Lomb Optical Co.
1961: 2 June, 1738; 8 Sept., 642
Fish-Schurman Corp.
1960: 21 Oct., 1152; 2 Dec., 1682
1961: 17 Feb., 517; 21 Apr., 1268
Mearl Corp.
1961: 22 Sept., 787
Photovolt Corp.
1961: 10 Feb., 393; 11 Aug., 398

Filters, Membrane

Millipore Filter Corp.
1961: 21 July, 234; 5 Aug., 300; 18 Aug., 502; 1 Sept., 624; 15 Sept., 744; 29 Sept., 957
Schleicher, Carl, & Schuell Co.
1960: 2 Dec., 1716

Filters, Polarizing

Pioneer Scientific Corp.
1960: 14 Oct., IBC; 9 Dec., 1734

Filters, Porcelain

Brinkmann Instruments, Inc.
1961: 7 Apr., 1087; 21 Apr., 1285

Flame Photometers

Baird-Atomic, Inc.
1960: 21 Oct., 1198; 11 Nov., 1408; 2 Dec., 1684
1961: 17 Feb., 502; 24 Mar., 928; 31 Mar., 968; 19 May, 1605; 16 June, 1880; 28 July, 246
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1961: 23 June, 2024
Brinkmann Instruments, Inc.
1961: 31 Mar., 1028
Coleman Instruments, Inc.
1960: 2 Dec., 1609
1961: 16 June, 1879; 18 Aug., 428
Zeiss, Carl, Inc.
1961: 31 Mar., 1028

Flasks, Culture

Bellco Glass, Inc.
1961: 21 Apr., 1299

Flasks, Spinner

Bellco Glass, Inc.
1960: 7 Oct., 970; 16 Dec., 1848

Flasks, Volumetric

Corning Glass Works
1961: 20 Jan., 144; 18 Aug., 426

Flow Counters, Radiation

Technical Associates
1961: 24 Mar., 822
Tracerlab, Inc.
1961: 24 Mar., 806

Flowmeters

Corning Glass Works
1961: 24 Mar., 838; 19 May, 1536
Gilmont, Roger, Instruments, Inc.
1961: 19 May, 1530
Ohio Chemical & Surgical Equipment Co.
1961: 24 Mar., 931
Phipps & Bird, Inc.
1961: 17 Mar., 773
Precision Scientific Co.
1961: 20 Jan., 198

Fluid Dispensers

Palo Laboratory Supplies, Inc.
1961: 21 Apr., 1300

Fluorometers, Photoelectric

Baird-Atomic, Inc.
1961: 16 June, 1880
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1961: 23 June, 2024
Coleman Instruments, Inc.
1960: 2 Dec., 1609
1961: 10 Feb., 354; 24 Mar., 831; 16 June, 1879; 21 July, 135
Farrand Optical Co., Inc.
1960: 2 Dec., 1697
Harshaw Scientific
1961: 13 Jan., 115

Klett Manufacturing Co.
1960: 21 Oct., 1152; 11 Nov., 1427
1961: 13 Jan., 117; 17 Mar., 773; 5 May, 1433; 25 Aug., 567; 6 Oct., 1025
Photovolt Corp.
1960: 14 Oct., 1025; 18 Nov., 1507; 30 Dec., 1949
1961: 13 Jan., 113; 24 Feb., 591; 31 Mar., 1023; 9 June, 1839; 14 July, 116; 25 Aug., 567; 15 Sept., 741
Will Corp.
1961: 21 July, 231

Fractionators, Counter Current

E-C Apparatus Co.
1960: 21 Oct., 1167
1961: 20 Jan., 217; 24 Mar., 790

Fraction Collectors, Gas

Hamilton Co., Inc.
1961: 5 May, 1448; 19 May, 1655
Packard Instrument Co., Inc.
1960: 21 Oct., 1054; 23 Dec., 1860
1961: 20 Jan., 164

Fraction Collectors, Liquid

Buchler Instruments, Inc.
1960: 2 Dec., 1600
1961: 21 Apr., 1273; 21 July, 219; 22 Sept., 762
Gilson Medical Electronics
1960: 25 Nov., 1567
Hamilton Co., Inc.
1960: 21 Oct., 1194
Research Specialties Co.
1961: 17 Feb., 496; 21 Apr., 1298
Vanguard Instrument Co.
1960: 11 Nov., 1350
1961: 24 Mar., 830; 21 July, 136; 22 Sept., 774

Freeze Drying Equipment

American Sterilizer Co.
1960: 21 Oct., 1071
1961: 20 Jan., 129; 19 May, 1517; 16 June, 1855; 18 Aug., 417; 22 Sept., 763
Instrumentation Associates, Inc.
1961: 2 June, IBC
Repp Industries, Inc.
1961: 21 July, 134
VirTis Co.
1960: 14 Oct., 984; 21 Oct., 1056; 11 Nov., 1344; 2 Dec., 1598
1961: 20 Jan., 138; 21 Apr., IBC; 19 May, 1638; 18 Aug., 501; 22 Sept., 769

Frequency Analyzers

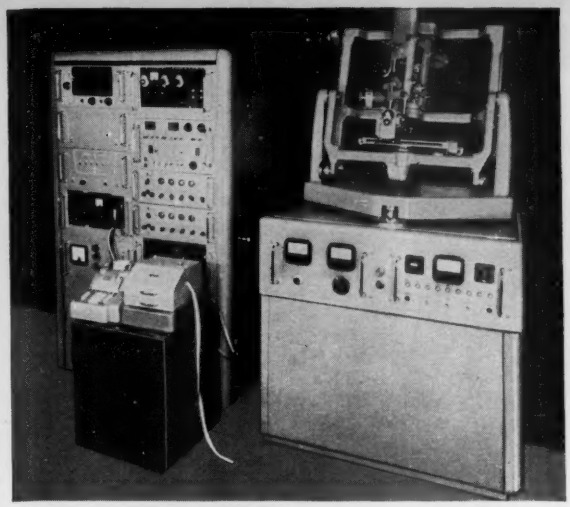
General Applied Science Laboratories, Inc.
1961: 21 Apr., 1300; 19 May, 1634; 16 June, 1958

Furnaces, Combustion Tube

Lindberg Engineering Co.
1961: 17 Feb., 529

Furnaces, Laboratory, General Purpose

Curtiss-Wright Corp.
1961: 21 Apr., 1274
Burrell Corp.
1961: 26 May, 1719
Lindberg Engineering Co.
1961: 17 Feb., 529; 21 Apr., 1273



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Thermolyne Corp.
1961: 24 Mar., 908; 21 Apr., 1306; 21 July 220; 18 Aug., 492; 22 Sept., 886

Furnaces, Ultra-High Temperature

Curtiss-Wright Corp.
1961: 18 Aug., 510

Furniture, Laboratory

Ajusto Equipment Co.
1961: 22 Sept., 852
Aloe Scientific
1961: 19 May, 1652; 22 Sept., 887
Duralab Equipment Corp.
1960: 21 Oct., 1193; 2 Dec., 1686
1961: 24 Mar., 910
Equipto
1961: 24 Mar., 947; 21 Apr., 1289; 19 May, 1647
Fisher Scientific Co.
1960: 21 Oct., 1086
1961: 5 May, 1387
Kewaunee Manufacturing Co.
1961: 19 May, 1610

Funnels, Separator

Kimble Glass Co.
1961: 24 Mar., 803

Galvanometers, Teaching

Central Scientific Co.
1961: 3 Feb., 338

Gas Containers, Liquid

Hofman Laboratories, Inc.
1961: 24 Mar., 942
Linde Co.
1960: 7 Oct., 962

Gases, Compressed

Matheson Co., Inc.
1961: 21 Apr., 1269; 16 June, 1956; 18 Aug., 419
Ohio Chemical & Surgical Equipment Co.
1961: 16 June, 1936

Gauges, Vacuum

Gilmont, Roger, Instruments, Inc.
1961: 22 Sept., 897
Greiner, Emil, Co.
1961: 22 Sept., 760

Gaussmeters

Harvey-Wells Corp.
1961: 18 Aug., 425

Generators, Signal

Strand Labs., Inc.
1961: 6 Oct., 1018

Germ-Free Apparatus

American Sterilizer Co.
1960: 11 Nov., 1351
1961: 16 June, 1855

Glass Blowing Equipment

Bethlehem Apparatus Co., Inc.
1960: 21 Oct., 1157; 2 Dec., 1704
1961: 22 Sept., 784

Glassware Coating, Plastic

Ace Glass, Inc.
1961: 24 Mar., 923

Glassware, Laboratory

Ace Glass, Inc.
1961: 19 May, 1643
Corning Glass Works
1960: 4 Nov., 1281; 11 Nov., 1420; 2 Dec., 1606
1961: 20 Jan., 144; 21 Apr., 1170; 21 July, 145; 18 Aug., 426; 22 Sept., 780; 6 Oct., 967
Delmar Scientific Laboratories
1961: 25 Aug., 571
Doerr Glass Co.
1960: 21 Oct., 1A
Greiner, Emil, Co.
1961: 19 May, 1534
Kimble Glass Co.
1960: 11 Nov., 1357; 9 Dec., 1731
1961: 21 Apr., 1173; 18 Aug., IBC
Kontes Glass Co.
1961: 24 Mar., 899
Thomas, Arthur H., Co.
1961: 5 May, BC

Glassware, Micro

Ace Glass, Inc.
1961: 19 May, 1643
Corning Glass Works
1961: 19 May, 1536
Delmar Scientific Laboratories
1961: 25 Aug., 571
Kontes Glass Co.
1961: 24 Feb., 595; 24 Mar., 899; 21 Apr., 1269

Glassware Washers

Chemical Rubber Co.
1961: 24 Mar., 958
Fisher Scientific Co.
1961: 31 Mar., 1027; 5 May, 1387

Gloves, Dry Box

Charleston Rubber Co.
1961: 24 Mar., 945; 19 May, 1645
Wilson Rubber Co.
1961: 6 Jan., IBC; 24 Mar., IBC; 6 Oct., IBC

Glow Boxes

Instruments for Research and Industry
1960: 21 Oct., 1200; 11 Nov., 1430
1961: 20 Jan., 225; 24 Mar., 935; 16 June, 1937; 18 Aug., 503

Graduates, Plastic

Nalge Co., Inc.
1961: 16 June, 1960; 18 Aug., 489

Growth Chambers, Plant

National Appliance Co.
1961: 19 May, 1609
Sherer-Gillett Co.
1961: 19 May, 1633

Heating Mantles

Glas-Col Apparatus Co.
1961: 26 May, 1671

Heating Tapes

Glas-Col Apparatus Co.
1961: 23 June, IBC; 25 Aug., 522
Standard Scientific Supply Corp.
1960: 11 Nov., 1434

Hematocrits, Micro

Yellow Springs Instrument Co., Inc.
1961: 28 Apr., 1372; 19 May, 1630; 22 Sept., 850

Homogenizers, Tissue

Brinkmann Instruments, Inc.
1961: 20 Jan., 208
Gifford-Wood Co.
1961: 24 Mar., 954
Heat Systems Co.
1961: 19 May, 1640
Instrumentation Associates, Inc.
1960: 11 Nov., 1406
Kontes Glass Co.
1960: 21 Oct., 1193; 11 Nov., 1410
1961: 20 Jan., 232; 19 May, 1634
Smith, Arthur F., Inc.
1960: 14 Oct., 1021
Sorvall, Ivan, Inc.
1961: 19 May, 1607; 18 Aug., 479
Tri-R Instruments
1961: 21 Apr., 1309
VirTis Co.
1961: 24 Mar., 796

Hoods, Fume

Blickman, S., Inc.
1960: 21 Oct., 1177
1961: 17 Feb., 525; 21 Apr., 1254; 18 Aug., 507
Kewaunee Scientific Equipment
1961: 21 July, 232
Laboratory Construction Co.
1961: 22 Sept., 873

Hoods, Microbiological

Blickman, S., Inc.
1960: 21 Oct., 1177
1961: 17 Feb., 525

Hoods, Radioactivity

Blickman, S., Inc.
1961: 17 Feb., 525; 16 June, 1936

Hot Plates

Harshaw Scientific
1961: 24 Mar., 952; 21 Apr., 1284
Lindberg Engineering Co.
1960: 11 Nov., 1425
1961: 24 Mar., 953; 19 May, 1618
New York Laboratory Supply Co.
1960: 2 Dec., 1719
Precision Scientific Co.
1960: 2 Dec., 1687
Standard Scientific Supply Corp.
1961: 21 Apr., 1258
Thermolyne Corp.
1960: 21 Oct., 1192; 2 Dec., 1678
1961: 20 Jan., 206; 17 Feb., 520; 16 June, 1942
Thomas, Arthur H., Co.
1961: 6 Oct., BC
Will Corp.
1960: 2 Dec., 1707

Hydrogen Determinaters

Coleman Instruments, Inc.
1961: 19 May, 1546
Fisher Scientific Co.
1961: 9 June, 1788

Hydrogenation Apparatus

Parr Instrument Co.
1961: 21 July, 216

Incubators, Co_2

National Appliance Co.
1960: 21 Oct., 1170
1961: 20 Jan., 213; 24 Mar., 946; 22 Sept., 856

Incubators, Dubnoff

Harshaw Scientific
1961: 13 Jan., 115

Insurance

Teachers Insurance and Annuity Assoc.
1961: 13 Jan., 116

Interferometers

Central Scientific Co.
1960: 16 Dec., 1849
Ercona Corp.
1960: 2 Dec., 1586
1961: 18 Aug., 412

Lathe, Metal Working

American Edestaal, Inc.
1960: 21 Oct., 1188; 2 Dec., 1703
1961: 24 Mar., 942; 21 Apr., 1300; 19 May, 1637; 16 June, 1945; 21 July, 202; 18 Aug., 502; 22 Sept., 880

Light Meters, Photoelectric

Photovolt Corp.
1960: 7 Oct., 967
Welch, W. M., Scientific Co.
1960: 7 Oct., 967

Liquid Scintillation Counters
See Counters, liquid scintillation, automatic

Logic Kits, Electronic

Digital Equipment Corp.
1960: 2 Dec., 1715

Magnetic Resonance Equipment, Nuclear
See Nuclear magnetic resonance equipment

Magnets, Electromagnetic

Harvey-Wells Corp.
1961: 16 June, 1851; 22 Sept., 757

Manometers

Corning Glass Works
1961: 24 Mar., 838; 19 May, 1536
Gilmont, Roger, Instruments, Inc.
1961: 24 Mar., 913
Greiner, Emil, Co.
1961: 19 May, 1614; 22 Sept., 760

Mass Spectrometers

Bendix Corp.
1960: 25 Nov., 1561
1961: 27 Jan., 287; 24 Mar., 933
High Voltage Engineering Corp.
1961: 20 Jan., 162
Picker X-Ray Corp.
1960: 21 Oct., 1073

Melting Point Apparatus

Gilford Instrument Laboratories, Inc.
1961: 6 Oct., 1022
Stoelting, C. H., Co.
1961: 17 Feb., 501
Thomas, Arthur H., Co.
1960: 21 Oct., 1075

Mercury Sweepers

Will Corp.
1961: 12 May, 1491
1961: 20 Jan., 124

Micromanipulators

Aloe Scientific
1960: 21 Oct., 1201
1961: 24 Mar., 917; 21 Apr., 1261
Brinkmann Instrument Co.
1960: 16 Dec., 1845
Ercona Corp.
1960: 21 Oct., 1162
1961: 19 May, 1522
Leitz, E., Inc.
1960: 18 Nov., IFC

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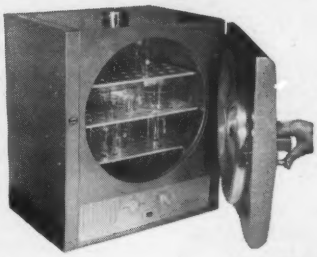

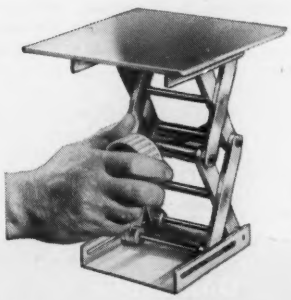

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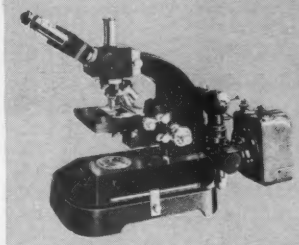

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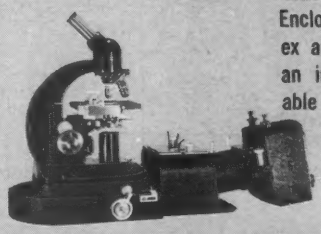

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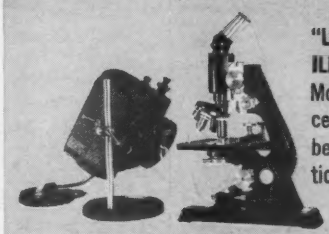

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Microscopes, Infrared

Erb & Gray Scientific, Inc.
1961: 25 Aug., 528

Microscopes, Interference

American Optical Co.
1961: 26 May, BC
Brinkmann Instruments, Inc.
1961: 28 Apr., 1375
Hacker, William J., & Co., Inc.
1961: 21 July, 234
Sobotka, Eric, Co.
1961: 20 Jan., 213

Microscopes, Medical

American Optical Co.
1961: 7 July, BC; 4 Aug., BC; 15 Sept., BC
Cooke, Troughton & Simms, Inc.
1960: 21 Oct., 1061; 11 Nov., 1347; 18 Nov., 1453; 2 Dec., 1601
1961: 20 Jan., 133; 17 Feb., 489; 24 Mar., 897; 26 May, 1717
Elgeet Optical Co., Inc.
1960: 7 Oct., 914; 21 Oct., 1052; 4 Nov., 1278
Ercona Corp.
1960: 21 Oct., 1162
Graf-Apsco Co.
1960: 21 Oct., 1156
Hacker, William J., & Co., Inc.
1961: 24 Mar., 933
Leitz, E., Inc.
1960: 4 Nov., 1338
1961: 3 Feb., 299; 17 Feb., IFC; 3 Mar., IFC; 17 Mar., IFC; 5 May, IFC; 4 Aug., IFC; 22 Sept., 845
Technical Instrument Co.
1960: 21 Oct., 1206
Unitron Instrument Co.
1960: 11 Nov., 1338; 30 Dec., 1908
1961: 24 Mar., 784; 28 July, 244
Wild Heerbrugg Instruments, Inc.
1961: 16 June, 1935
Zeiss, Carl, Inc.
1961: 24 Mar., 817

Microscopes, Metallurgical

Bausch & Lomb Optical Co.
1960: 4 Nov., 1284
Cooke, Troughton & Simms, Inc.
1960: 18 Nov., 1453
Ercona Corp.
1961: 24 Mar., 841; 22 Sept., 789
Hacker, William J., & Co., Inc.
1961: 21 July, 234
Unitron Instrument Co.
1960: 21 Oct., 1208; 11 Nov., 1338; 25 Nov., 1566; 30 Dec., 1908
1961: 20 Jan., 124; 26 May, 1666; 23 June, 1974

Microscopes, Phase

American Optical Co.
1960: 2 Dec., BC
1961: 14 Apr., BC
Brinkmann Instruments, Inc.
1961: 3 Mar., 650
Galileo Corporation of America
1961: 22 Sept., 890
Hacker, William J., & Co., Inc.
1960: 2 Dec., 1604
1961: 21 July, 234; 18 Aug., 485; 22 Sept., 895

Ercona Corp.
1960: 21 Oct., 1162
Leitz, E., Inc.
1960: 21 Oct., IFC
Scientific Glass Apparatus Co., Inc.
1961: 17 Feb., 409
Sobotka, Eric, Co.
1960: 21 Oct., 1196; 18 Nov., 1505; 2 Dec., 1683
Unitron Instrument Co.
1960: 7 Oct., 970; 21 Oct., IBC; 11 Nov., 1338; 9 Dec., 1728; 16 Dec., 1847; 30 Dec., 1908
1961: 27 Jan., 286; 17 Feb., 400; 10 Mar., 717; 14 Apr., 1096; 21 Apr., 1292; 19 May, 1637; 9 June, 1837; 7 July, 64; 11 Aug., 400; 22 Sept., 752; 29 Sept., 954
Wild Heerbrugg Instruments, Inc.
1960: 21 Oct., 1165; 11 Nov., 1407
1961: 20 Jan., 223; 17 Feb., 507; 24 Feb., 593; 19 May, 1621

Microscopes, Stereoscopic, Zoom

Bausch & Lomb Optical Co.
1960: 21 Oct., 1090
1961: 10 Mar., 667; 21 Apr., 1196; 9 June, 1792; 16 June, 1884
Ercona Corp.
1961: 19 May, 1522
Harshaw Scientific
1961: 26 May, 1720
Scientific Glass Apparatus Co., Inc.
1961: 24 Mar., 948

Microscopes, Student

American Optical Co.
1961: 15 Sept., BC
Bausch & Lomb Optical Co.
1960: 16 Dec., 1796
1961: 13 Jan., 72; 28 Apr., 1326; 19 May, 1558; 30 June, 2038; 28 July, 250

Microscopes, Television

Elgeet Optical Co., Inc.
1960: 18 Nov., 1455; 2 Dec., 1582; 19 Dec., 1793
1961: 20 Jan., 158; 17 Feb., 429

Microscopes, X-ray

Philips Electronics Instruments
1961: 18 Aug., 483

Microtome Knife Sharpener

American Optical Co.
1961: 6 Jan., BC; 9 June, BC

Microtomes, Bone

Bronwill Scientific, Div. of Will Corp.
1961: 24 Mar., 925

Microtomes, General Purpose

American Optical Co.
1961: 17 Feb., BC
Brinkmann Instruments, Inc.
1960: 2 Dec., 1699
Hacker, William J., & Co., Inc.
1961: 17 Feb., 531

Microtomes, Refrigerated

Hacker, William J., & Co., Inc.
1960: 2 Dec., 1604
1961: 17 Feb., 531
International Equipment Co.
1960: 25 Nov., 1516; 2 Dec., 1579; 23 Dec., 1856
1961: 3 Feb., 296; 28 Apr., 1319; 26 May, 1669; 14 July, 74
National Instrument Laboratories, Inc.
1960: 21 Oct., 1121

Microtomes, Ultra

Cambridge Instrument Co., Inc.
1961: 19 May, 1641
Hacker, William J., & Co., Inc.
1960: 2 Dec., 1604
Leitz, E., Inc.
1960: 21 Oct., 1216
1961: 7 July, IFC; 21 July, IFC
LKB Instruments, Inc.
1960: 2 Dec., 1591
1961: 20 Jan., 136; 17 Feb., 418; 19 May, 1553

Cooke, Troughton & Simms, Inc.
1961: 26 May, 1717
Edmund Scientific Co.
1960: 25 Nov., 1519
Elgeet Optical Co., Inc.
1960: 7 Oct., 914; 21 Oct., 1052; 4 Nov., 1279
1961: 24 Mar., 813; 7 Apr., IBC; 16 June, 1870; 21 July, 138; 22 Sept., 792
Graf-Apsco Co.
1961: 13 Jan., 117; 17 Feb., 501
Harshaw Scientific
1961: 14 July, 117
Leitz, E., Inc.
1961: 2 June, 1732
Unitron Instrument Co.
1960: 14 Oct., 1024; 21 Oct., IBC; 28 Oct., 1268; 9 Dec., 1728
1961: 13 Jan., 111; 24 Feb., 594; 17 Mar., 768; 7 Apr., 1040; 21 July, 244; 15 Sept., 744

Schuco Scientific, Div. of Schueler & Co.
1960: 11 Nov., 1427
Sorvall, Ivan, Inc.
1961: 21 July, 148; 18 Aug., 479; 22 Sept., 771

Microwave, Power Generator Systems

Raytheon Co.
1960: 21 Oct., 1032; 11 Nov., 1336
1961: 20 Jan., 222; 17 Feb., 506; 24 Mar., 930; 16 Apr., 1277; 19 May, 1627; 16 June, 1952; 18 Aug., 498

Mills, Colloid

Gifford-Wood Co.
1961: 16 June, 1944

Mixers, Test Tube
See Test tube mixers

Models, Crystal Lattice

Bronwill Scientific, Div. of Will Corp.
1960: 18 Nov., 1505
1961: 21 Apr., 1270; 18 Aug., 493
Central Scientific Co.
1961: 19 May, 1649; 22 Sept., 847
Ealing Corp.
1961: 7 July, 58
LaPine, Arthur S., and Co.
1960: 21 Oct., 1160
Will Corp.
1961: 12 May, 1491; 22 Sept., 877

Moisture Determinators

Nuclear-Chicago Corp.
1960: 28 Oct., BC
1961: 27 Jan., BC
Scientific Glass Apparatus Co., Inc.
1961: 19 May, 1506

Monitors, Radiation

Atomic Accessories, Inc.
1961: 22 Sept., 798
Lionel Electronic Laboratories (formerly Anton Electronic Laboratories, Inc.)
1960: 21 Oct., 1149
1961: 21 Apr., 1283
Technical Associates
1960: 21 Oct., 1036

Monochromators

Bausch & Lomb Optical Co.
1961: 8 Sept., 642
Farrand Optical Co., Inc.
1960: 7 Oct., 965
Photovolt Corp.
1961: 10 Mar., 712; 26 May, 1723
Rudolph, O. C., & Sons, Inc.
1961: 17 Feb., 512

Mortars and Pestles

Coors Porcelain Co.
1961: 21 July, 216

Motors, Variable Speed

Bel-Art Products
1961: 17 Feb., 521
Heller, Gerald K., Co.
1961: 20 Jan., 207; 17 Feb., 509; 21 Apr., 1281; 19 May, 1644; 16 June, 1941; 21 July, 209; 18 Aug., 481; 22 Sept., 871

Microwave Spectrometers

Strand Labs., Inc.
1961: 6 Oct., 1018

Multichannel Analyzers
See Pulse height analyzers

Needle Valves, Teflon

Greiner, Emil, Co.
1961: 21 July, 140

Needles, Special Purpose

Hamilton Co., Inc.
1961: 12 May, 1448

Nephelometers

Coleman Instruments, Inc.
1961: 16 June, 1879; 21 July, 135
Klett Manufacturing Co.
1961: 5 May, 1433

Neutron Sources

Atomic Accessories, Inc.
1961: 20 Jan., 219
High Voltage Engineering Corp.
1960: 16 Dec., 1794
1961: 20 Jan., 162; 23 June, 1978
Lionel Electronic Laboratories (formerly Anton Electronic Laboratories, Inc.)
1961: 19 May, 1617; 21 July, 207
Nuclear-Chicago Corp.
1960: 25 Nov., BC; 23 Dec., BC
1961: 24 Feb., BC; 8 Sept., 634, 635

Nitrogen Analyzers

Coleman Instruments, Inc.
1961: 19 May, 1546
Fisher Scientific Co.
1960: 11 Nov., 1349
1961: 9 June, 1789

Nuclear Magnetic Resonance Equipment

Harvey-Wells Corp.
1961: 18 Aug., 425
Picker X-Ray Corp.
1960: 21 Oct., 1073

Operating Equipment, Animal

Aloe Scientific
1961: 18 Aug., 499

Oscilloscopes

Welch, W. M., Scientific Co.
1961: 2 June, 1779

Osmometers

Mechrolab, Inc.
1960: 21 Oct., 1148; 11 Nov., 1406; 9 Dec., 1776

Ovens, Laboratory, General Purpose

Central Scientific Co.
1961: 16 June, 1939
Despatch Oven Co.
1960: 21 Oct., 1186
1961: 20 Jan., 210; 19 May, 1624
Electric Hotpack Co., Inc.
1961: 20 Jan., 227; 24 Mar., 925

Fisher Scientific Co.
1960: 2 Dec., 1588
Precision Scientific Co.
1960: 21 Oct., 1164
Scientific Glass Apparatus Co., Inc.
1960: 21 Oct., 1059
Temperature Engineering Corp.
1961: 21 July, 214

Ovens, Paraffin

Will Corp.
1961: 12 May, 1491

Ovens, Vacuum

National Appliance Co.
1960: 11 Nov., 1416
Temperature Engineering Corp.
1961: 19 May, 1650

Oxygen Analyzers

Beckman Instruments, Inc.
1960: 14 Oct., 1018
1961: 6 Jan., 56; 28 Apr., IFC
Fisher Scientific Co.
1960: 11 Nov., 1349
1961: 9 June, 1788
Gilson Medical Electronics
1960: 30 Dec., 1947
1961: 19 May, 1654; 29 Sept., 904

Paint, Heat Sensitive

Curtiss-Wright Corp.
1960: 2 Dec., 1672

Particle Size Analyzers

Coulter Electronics, Inc.
1961: 24 Mar., 958
Dietert, Harry W., Co.
1960: 21 Oct., 1200
1961: 17 Feb., 500
Zeiss, Carl, Inc.
1960: 21 Oct., 1043
1961: 6 Jan., 6; 19 May, 1518

Perimeters

Phipps & Bird, Inc.
1961: 18 Aug., 511; 22 Sept., 879

Petri Dishes, Plastic

Falcon Plastics
1960: 21 Oct., 1037
Scientific Products, Div. of American Hospital Supply Corp.
1961: 24 Mar., 798

***p*H Electrodes**

Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 11 Nov., 1430

***p*H Meters**

Analytical Measurements, Inc.
1961: 6 Oct., 1016
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 18 Nov., 1451
1961: 17 Feb., 492; 10 Mar., 672; 21 Apr., 1279
Brinkmann Instruments, Inc.
1960: 14 Oct., 980; 4 Nov., 1276
1961: 22 Sept., 847

Photomultiplier Tubes

CBS Laboratories
1960: 21 Oct., 1160
1961: 20 Jan., 199; 22 Sept., 896
Radio Corporation of America
1960: 30 Dec., BC

Physiological Teaching Equipment

Harvard Apparatus Co.
1960: 11 Nov., 1413

Pipette Fillers

Instrumentation Associates
1961: 2 June, 1778

Pipette Jars, Plastic

Nalge Co., Inc.
1961: 24 Mar., 921

Pipette Pluggers

Bellco Glass, Inc.
1961: 21 July, 231; 4 Aug., 347; 18 Aug., 491; 22 Sept., 871; 6 Oct., 1021

Pipettes, Automatic

Kimble Glass Co.
1961: 17 Feb., IBC
Lapine, Arthur S., & Co.
1960: 2 Dec., 1683
1961: 17 Feb., 534; 21 July, 222

Schuco Scientific, Div. of Schueler & Co.
1960: 25 Nov., 1563
Scientific Industries, Inc.
1960: 2 Dec., 1708
1961: 19 May, 1659

Pipettes, Hand

Bellco Glass, Inc.
1961: 3 Feb., 335; 17 Feb., 532; 10 Mar., 713; 7 Apr., 1085; 19 May, 1610
Hamilton Co., Inc.
1961: 16 June, 1930
Kimble Glass Co.
1961: 17 Feb., IBC; 19 May, IBC; 16 June, IBC; 21 July, IBC; 15 Sept., IBC
Thomas, Arthur H., Co.
1961: 16 June, BC

Pipettes, Micro

Hamilton Co., Inc.
1961: 12 May, 1448
LaPine Scientific Co.
1961: 21 July, 222
Research Specialties Co.
1961: 12 May, 1495
Thomas, Arthur H., Co.
1961: 14 July, BC

Plant Growth Chambers

Percival Refrigeration & Manufacturing Co.
1961: 24 Mar., 914; 22 Sept., 854
Sherer-Gillett Co.
1961: 24 Mar., 949

Plastic Ware, Laboratory

Falcon Plastics
1960: 21 Oct., 1037
Nalge Co., Inc.
1960: 21 Oct., 1072
U.S. Stoneware
1961: 24 Mar., 916; 19 May, 1615; 22 Sept., 864

Polariscopes

Bethlehem Apparatus Co., Inc.
1960: 21 Oct., 1187

Polarimeters

Kern Co.
1960: 7 Oct., 964
Zeiss, Carl, Inc.
1961: 11 Aug., IBC

Polarographic Analyzers

American Optical Co.
1961: 12 May, BC
Leeds & Northrup Co.
1960: 21 Oct., 1040
London Co.
1961: 19 May, 1550
Sargent, E. H., & Co.
1960: 11 Nov., 1365
1961: 20 Jan., 153; 24 Mar., 814; 21 July, 142
Standard Scientific Supply Corp.
1961: 21 July, 230

Polaroid Filters

Pioneer Scientific Corp.
1960: 14 Oct., IBC; 11 Nov., 1358

Polishers, Electrolytic

Ercona Corp.
1961: 24 Mar., 841; 22 Sept., 789

Porcelain Ware, Laboratory

Coors Porcelain Co.
1961: 20 Jan., 200; 19 May, 1656; 22 Sept., 868

Potentiometers

Leeds & Northrup Co.
1960: 21 Oct., 1040

Power Supplies, High Voltage

Harvey-Wells Corp.
1961: 19 May, 1523
Mikros Inc.
1961: 21 July, 236
Servonuclear Corp.
1960: 21 Oct., 1156
1961: 26 May, 1726
Zeiss, Carl, Inc.
1960: 7 Oct., IBC
1961: 16 June, 1873

Power Supplies, Low Voltage

National Instrument Laboratories, Inc.
1960: 21 Oct., 1121
Philbrick, George A., Researches, Inc.
1961: 18 Aug., 478
Phipps & Bird, Inc.
1961: 21 Apr., 1305; 28 Apr., 1371

Precipitators, Thermal

Ficklen, Joseph B., III
1961: 6 Oct., 1018

Projectors, Opaque

Edmund Scientific Co.
1961: 20 Jan., 151

Protein Analyzers

Bausch & Lomb Optical Co.
1961: 17 Feb., 550; 24 Mar., 848; 5 May, 1394; 4 Aug., 302
Laboratory Construction Co.
1960: 21 Oct., 1197
Technicon Chromatography Corp.
1961: 24 Mar., 905; 21 July, 226

Protein Meters

Bausch & Lomb Optical Co.
1960: 30 Dec., 1912
1961: 22 Sept., 802; 6 Oct., 972

Pulse Generators

Radiation Instrument Development Laboratory, Inc.
1960: 21 Oct., 1042

Pulse Height Analyzers

Baird Atomic, Inc.
1960: 21 Oct., 1083
1961: 16 June, 1853
Hamner Electronics Co., Inc.
1961: 22 Sept., 892
Nuclear-Chicago Corp.
1961: 19 May, BC
Radiation Counter Laboratories, Inc.
1961: 16 June, 1A

Radiation Instrument Development Laboratory, Inc.
1960: 21 Oct., 1042
1961: 24 Mar., 820
Technical Measurement Corp.
1960: 7 Oct., 922; 21 Oct., 1088; 18 Nov., 1456; 2 Dec., 1614
1961: 13 Jan., 70; 17 Feb., 440; 10 Mar., 670; 21 Apr., 1194; 12 May, 1452; 16 June, 1882; 21 July, 158; 25 Aug., 530; 15 Sept., 700; 6 Oct., 970
Victoreen Instrument Co.
1960: 21 Oct., 1079

Pumps, Infusion

Harvard Apparatus Co.
1960: 21 Oct., 1179
1961: 17 Feb., 501; 21 Apr., 1164
Phipps & Bird, Inc.
1960: 2 Dec., 1703
1961: 2 June, 1722
Sigmamotor, Inc.
1961: 22 Sept., 863
Will Corp.
1960: 11 Nov., 1419

Pumps, Liquid, Constant Volume

Randolph Co.
1961: 19 May, 1659
Scientific Glass Apparatus Co., Inc.
1961: 22 Sept., 888
Sigmamotor, Inc.
1960: 21 Oct., 1167; 2 Dec., 1682
1961: 17 Feb., 517; 21 Apr., 1270

Pumps, Peristaltic

Harvard Apparatus Co.
1961: 17 Feb., 501; 21 July, 209

Pumps, Respiratory

Harvard Apparatus Co.
1961: 17 Feb., 501; 24 Mar., 907; 21 July, 209
Phipps & Bird, Inc.
1960: 11 Nov., 1414
1961: 24 Feb., 591; 3 Mar., 657; 7 Apr., 1089; 14 Apr., 1138; 12 May, 1494; 19 May, 1648

Pumps, Vacuum

Central Scientific Co.
1960: 21 Oct., 1051
Kinney Vacuum Div., New York Air Brake Co.
1960: 21 Oct., 1177; 2 Dec., 1719
LaPine Scientific Co.
1961: 24 Mar., 920
Precision Scientific Co.
1961: 24 Mar., 909
Standard Scientific Supply Corp.
1961: 6 Oct., 1024
Welch, W. M., Scientific Co.
1961: 7 Apr., 1084; 7 July, 63; 6 Oct., 1015

Pumps, Vacuum, Diffusion

NRC Equipment Corp.
1961: 21 Apr., 1268

Pumps, Vacuum, Ionic

Hughes, Vacuum Tube Products Div.
1960: 21 Oct., 1195
1961: 20 Jan., 203; 24 Mar., 941

Pycnometers

Scientific Glass Apparatus Co., Inc.
1961: 17 Feb., 409

Pyrometers

Thermolyne Corp.
1961: 19 May, 1651

Quartz Ware, Laboratory

Thermal American Fused Quartz Co., Inc.
1961: 17 Feb., 526; 24 Mar., 934; 21 Apr., 1306; 16 June, 1938; 18 Aug., 504

Radiation Counters, Scalers and Rate Meters

See Counters, liquid scintillation, automatic; Counters and scalers, gamma radiation; Counters and scalers, low-level radiation

Radiation Detectors

See Detectors, radiation

Radiation Monitors

See Monitors, radiation

Radiation Shields

See Shields, radiation

Radioisotopes

See Chemicals, radiation

Ratemeters, Nuclear

See Counters and scalers, gamma radiation; Counters and scalers, low-level radiation

Rats, Laboratory

Charles River Breeding Laboratories
1960: 7 Oct., 974
Sprague Dawley, Inc.
1960: 4 Nov., 1324; 18 Nov., 1505

Reaction Vessels, Laboratory

Ace Glass, Inc.
1961: 20 Jan., 224
Parr Instrument Co.
1961: 24 Mar., 904

Reactors, Nuclear Training

Nuclear-Chicago Corp.
1960: 28 Oct., BC
1961: 8 Sept., 635

Recorder Controllers

Research, Inc.
1961: 16 June, 1934; 22 Sept., 872

Recorders, Graphic

American Optical Co.
1961: 21 July, BC
Atomic Accessories, Inc.
1961: 16 June, 1852
Beckman Instrument, Inc., Scientific and Process Instruments Div.
1960: 16 Dec., 1846
1961: 17 Feb., 492; 29 Sept., 910
Curtiss-Wright Corp.
1961: 17 Feb., 494; 19 May, 1629; 21 July, 205

Esterline-Angus Co.
1960: 21 Oct., 1184; 11 Nov., 1410; 2 Dec., 1706
1961: 20 Jan., 149; 24 Mar., 799; 19 May, 1554; 21 July, 210; 5 Aug., 437
Fisher Scientific Co.
1960: 9 Dec., 1736
1961: 21 Apr., 1297
Gilford Instrument Laboratories, Inc.
1961: 6 Oct., 1022
Houston Instrument Corp.
1960: 21 Oct., 1175
1961: 20 Jan., 230; 17 Feb., 532; 24 Mar., 938; 21 Apr., 1299; 19 May, 1642; 16 June, 1930; 21 July, 206; 22 Sept., 880
Leeds & Northrup Co.
1960: 21 Oct., 1040
Minneapolis-Honeywell, Heiland Div.
1961: 20 Jan., 128; 17 Feb., 439; 24 Mar., 832; 21 Apr., 1184; 19 May, 1540; 16 June, 1876; 21 July, 149; 18 Aug., 430; 22 Sept., 793
Photovolt Corp.
1960: 25 Nov., 1563; 23 Dec., 1901
1961: 6 Jan., 49; 3 Feb., 338; 7 Apr., 1084; 12 May, 1495; 2 June, 1776; 7 July, 64; 4 Aug., 347; 1 Sept., 623; 29 Sept., 954; 6 Oct., 1016
Sanborn Co.
1961: 17 Feb., 414; 14 Apr., 1135; 29 Sept., IFC
Sargent, E. H., & Co.
1960: 21 Oct., 1046
1961: 17 Feb., 420; 16 June, 1858; 6 Oct., 969
Scientific Products, Div. of American Hospital Supply Corp.
1960: 2 Dec., 1594
Smith, Arthur F., Inc.
1960: 7 Oct., 968; 4 Nov., 1326; 2 Dec., 1680
Standard Scientific Supply Corp.
1961: 19 May, 1636
Stoelting, C. H., Co.
1960: 7 Oct., 970; 2 Dec., 1705
1961: 21 Apr., 1268
Texas Instrument Co.
1960: 21 Oct., 1053; 2 Dec., 1583
1961: 24 Mar., 809; 19 May, 1515; 21 July, 155
Thomas, Arthur H., Co.
1960: 14 Oct., BC
Varian Associates
1961: 6 Jan., 52
Yellow Springs Instrument Co.
1961: 20 Jan., 225

Recorders, Integrating

Atomic Accessories, Inc.
1961: 16 June, 1852
Fisher Scientific Co.
1961: 21 Apr., 1297; 23 June, 2025
Ridgefield Instrument Group, a Schlumberger Div.
1961: 18 Aug., 484
Texas Instruments, Inc.
1961: 22 Sept., 767

Recorders, Tape

Mnemotron Corp.
1961: 2 June, 1734
Precision Instrument Co.
1960: 7 Oct., 963; 21 Oct., 1055; 4 Nov., 1323; 11 Nov., 1433; 2 Dec., 1693
1961: 6 Jan., 53; 3 Feb., 339; 24 Mar., 943; 14 Apr., 1136
Sanborn Co.
1961: 18 Aug., 410

Refractometers, Differential

Ercona Corp.
1960: 2 Dec., 1586
1961: 18 Aug., 412
Phoenix Precision Instrument Co.
1960: 21 Oct., 1199
1961: 20 Jan., 210; 22 Sept., 852
Waters Associates
1961: 24 Mar., 919

Refrigerators, Sub-Zero

Cyrogenic Engineering Co.
1961: 22 Sept., 876
Custom Scientific Instruments, Inc.
1960: 21 Oct., 1196
1961: 17 Feb., 432; 21 Apr., 1180
Instrumentation Associates, Inc.
1961: 2 June, IBC
Linde Co.
1960: 7 Oct., 962; 2 Dec., 1694
1961: 13 Jan., 110; 24 Mar., 950; 21 Apr., 1290; 16 June, 1943
Standard Scientific Supply Corp.
1961: 17 Feb., 508

Restrainers, Animal

Foringer & Co., Inc.
1960: 7 Oct., 971

Resuscitators

Ohio Chemical & Surgical Equipment Co.
1961: 19 May, 1644; 22 Sept., 852

Safety Enclosures

Blickman, S., Inc.
1960: 21 Oct., 1177

Sample Changers, Isotope Automatic

Baird-Atomic, Inc.
1961: 21 July, 144; 18 Aug., 420
Sharp Laboratories, Inc.
1960: 21 Oct., 1185
Technical Associates
1960: 21 Oct., 1036
1961: 19 May, 1552
Tracerlab, Inc.
1961: 17 Feb., 438; 5 May, 1392

Scales

Exact Weight Scale Co.
1961: 24 Mar., 937; 22 Sept., 891
Pennsylvania Scale Co.
1961: 22 Sept., 849

Scalers, Nuclear

See Counters and scalers, gamma radiation; Counters and scalers, low-level radiation

Scanners, Chromatogram

See Chromatogram scanners

Schedule Boards

Graphic Systems
1960: 11 Nov., 1416
1961: 24 Mar., 920; 21 July, 202; 22 Sept., 856

Scintillation Counters

See Counters, scintillation

Scintillation Crystals

See Crystals, scintillation

Scintillation Probes

Atomic Accessories, Inc.
1960: 21 Oct., 1202
Picker X-Ray Corp.
1960: 18 Nov., 1447

Scintillation Well Detectors

Nuclear-Chicago Corp.
1960: 28 Oct., BC
1961: 27 Jan., BC
Packard Instrument Co., Inc.
1961: 26 May, 1678

Serums

Colorado Serum Co.
1961: 17 Feb., 509

Serums, Biological

Hyland Laboratories
1960: 2 Dec., 1702

Shakers, General Purpose

New Brunswick Scientific Co., Inc.
1960: 11 Nov., 1409; 18 Nov., 1507; 25 Nov., 1563
1961: 6 Jan., 49; 21 Apr., 1294

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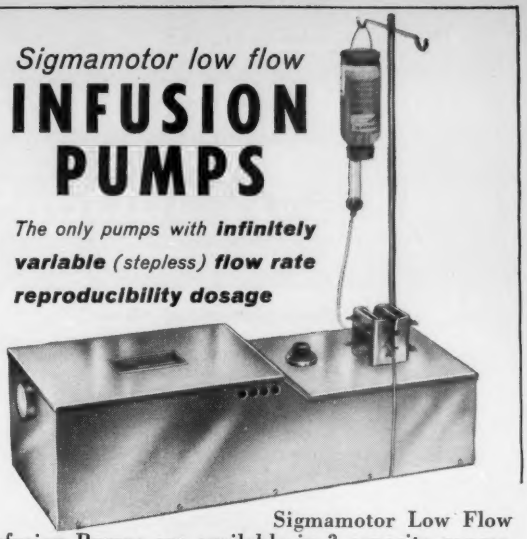

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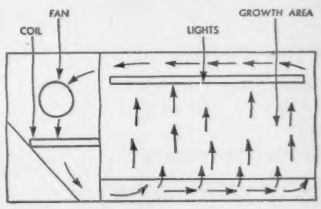

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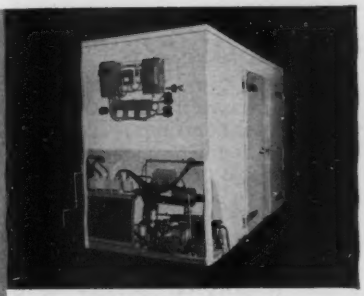

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Field of Research_____

Shakers, Gyrotory

New Brunswick Scientific Co., Inc.
1960: 9 Dec., 1779

Shakers, Incubator

New Brunswick Scientific Co., Inc.
1960: 18 Nov., 1507
1961: 20 Jan., 215; 24 Mar., 919; 19 May, 1519; 1 Sept., 623; 22 Sept., 785

Shakers, Water Bath

New Brunswick Scientific Co., Inc.
1960: 2 Dec., 1705
1961: 21 Apr., 1294; 15 Sept., 741
Research Specialties Co.
1961: 19 May, 1608

Shields, Radiation

Technical Associates
1960: 21 Oct., 1036
1961: 19 May, 1552

Sieves, Laboratory

Custom Scientific Instruments, Inc.
1961: 16 June, 1862

Sinks, Laboratory, Porcelain

U.S. Stoneware
1961: 20 Jan., 211; 21 July, 233

Skeleton Models, Human

Welch, W. M., Scientific Co.
1961: 6 Jan., 55
Clay-Adams
1961: 21 July, 157

Soil Testing Kits

Edmund Scientific Co.
1961: 19 May, 1533

Sonic Oscillators

Raytheon Co.
1960: 2 Dec., 1689
1961: 21 Apr., 1277; 19 May, 1627; 21 July, 221; 22 Sept., 865

Spectral Lamps

Ealing Corp.
1961: 22 Sept., 872

Spectro Fluorometers

Farrand Optical Co., Inc.
1960: 11 Nov., 1413

Spectrographs

Baird-Atomic, Inc.
1961: 7 July, 4; 21 July, 124; 11 Aug., 356
Bausch & Lomb Optical Co.
1961: 17 Mar., 771; 11 Aug., 360

Spectrometers, Mass
See Mass spectrometer

Spectrophotometers, Data Plotter

Connecticut Instrument Corp.
1960: 2 Dec., 1711

Spectrophotometers, Infrared

Baird-Atomic, Inc.
1961: 5 May, 1439; 19 May, 1510
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 21 Oct., 1039; 9 Dec., 1732
1961: 27 Jan., 250; 10 Feb., 348; 28 Apr., 1323; 26 May, 1673; 30 June, 2036; 21 July, 127; 25 Aug., 526
Perkin-Elmer Corp.
1960: 21 Oct., 1034; 18 Nov., 1448
1961: 13 Jan., 64; 10 Mar., 664; 25 Aug., 520; 29 Sept., BC

Spectrophotometers, Micro

Beckman Instruments, Inc., Spinco Div.
1961: 8 Sept., IFC
Brinkmann Instruments, Inc.
1961: 17 Feb., 520
Canal Industrial Corp.
1960: 21 Oct., 1171
1961: 17 Feb., 515
Coleman Instruments, Inc.
1961: 16 June, 1879; 21 July, 135
Standard Scientific Supply Corp.
1961: 16 June, 1932

Spectrophotometers, Visible and Ultraviolet

Applied Physics Corp.
1961: 20 Jan., 222; 31 Mar., 959; 7 July, 61; 18 Aug., 496; 22 Sept., 869
Bausch & Lomb Optical Co.
1960: 7 Oct., 924
1961: 27 Jan., 254; 7 Apr., 1044; 7 July, 12
Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 7 Oct., 915; 9 Dec., 1732
1961: 13 Jan., 68, 69; 24 Mar., 845; 26 May, 1673; 25 Aug., 526; 22 Sept., 761
Coleman Instruments, Inc.
1960: 2 Dec., 1609
1961: 10 Feb., 354; 16 June, 1879; 21 July, 135
Harshaw Scientific
1961: 11 Aug., 399; 22 Sept., 862; 6 Oct., 1023
Perkin-Elmer Corp.
1961: 19 May, 1504; 16 June, 1846; 14 July, 72; 18 Aug., 415; 1 Sept., 580; 15 Sept., 692; 29 Sept., BC
Sargent, E. H., & Co.
1961: 6 Oct., 969
Scientific Products, Div. of American Hospital Supply Corp.
1960: 21 Oct., 1076
1961: 17 Feb., 406; 21 Apr., 1162
Zeiss, Carl, Inc.
1960: 2 Dec., 1599

Spectropolarimeters

Rudolph Instruments Engineering Co.
1960: 21 Oct., 1064
1961: 24 Mar., 926

Spectroscopes

Bausch & Lomb Optical Co.
1961: 19 May, 1558
Ealing Corp.
1961: 16 June, 1965; 22 Sept., 872
Fisher Scientific Co.
1961: 24 Mar., 843

Sterilizers

American Sterilizer Co.
1960: 11 Nov., 1351
1961: 20 Jan., 129; 16 June, 1855
Wilmot Castle Co.
1960: 14 Oct., 982; 21 Oct., 1038; 2 Dec., 1597
1961: 20 Jan., 150; 24 Mar., 818; 21 Apr., 1190; 26 May, 1675; 16 June, 1860; 21 July, 126; 25 Aug., 1A; 22 Sept., 782

Stills, Vacuum

Greiner, Emil, Co.
1961: 20 Jan., 216
Smith, Arthur F., Inc.
1960: 21 Oct., 1188; 25 Nov., 1564

Stills, Water

Ace Glass, Inc.
1961: 21 July, 215
American Sterilizer Co.
1960: 11 Nov., 1351
1961: 20 Jan., 129; 16 June, 1855
Barnstead Still and Sterilizer Co.
1960: 21 Oct., 1168
1961: 20 Jan., 230
Bellco Glass, Inc.
1961: 19 May, 1624; 16 June, 1961; 30 June, 2073; 7 July, 63
Stokes, F. J., Corp.
1961: 19 May, 1612; 16 June, 1965; 21 July, 206; 18 Aug., 503; 22 Sept., 860
Wilmot Castle Co.
1960: 11 Nov., 1342; 25 Nov., 1571
1961: 17 Feb., 405

Stimulators, Electronic

American Electronic Laboratories, Inc.
1960: 11 Nov., 1428; 2 Dec., 1713
1961: 20 Jan., 235; 17 Feb., 513; 24 Mar., 898; 19 May, 1609; 16 June, 1957; 22 Sept., 861
Foringer & Co., Inc.
1960: 7 Oct., 971

Stirrers, Electric

Heller, Gerald K., Co.
1960: 21 Oct., 1186; 11 Nov., 1414; 25 Nov., 1566; 9 Dec., 1772
Scientific Industries, Inc.
1960: 18 Nov., 1505
1961: 20 Jan., 200
Smith, Arthur F., Inc.
1960: 14 Oct., 1021
Wilkins-Anderson Co.
1961: 24 Mar., 935

Stirrers, Magnetic

Central Scientific Co.
1961: 16 June, 1939
LaPine, Arthur S., and Co.
1960: 21 Oct., 1160
Thermolyne Corp.
1961: 16 June, 1942
Thomas, Arthur H., Co.
1961: 6 Oct., BC
Tri-R Instruments
1960: 21 Oct., 1203
1961: 17 Feb., 537

Stools, Laboratory

Adjusto Equipment Co.
1960: 21 Oct., 1152; 2 Dec., 1685
1961: 24 Mar., 901; 22 Sept., 852

Stopcocks, Teflon

Corning Glass Works
1961: 17 Feb., 407; 21 Apr. 1170
Kimble Glass Co.
1960: 9 Dec., 1731
1961: 6 Jan., 4; 24 Mar., 803

Sulfur Determinators

Dietert, Harry W., Co.
1961: 19 May, 1630

Surface Tension Apparatus

Fisher Scientific Co.
1961: 9 June, 1789

Survey Meters, Radiation

See Monitors, radiation

Syringes, Constant Rate

JKM Instrument Co.
1961: 21 July, 137; 18 Aug., 431

Syringes, Infusion

Will Corp.
1960: 21 Oct., 1041
1961: 24 Mar., 956

Syringes, Micro, Gas

Hamilton Co., Inc.
1960: 30 Dec., 1907
1961: 21 Apr., 1167; 5 May, 1391; 22 Sept., 882

Syringes, Micro, Liquid

Hamilton Co., Inc.
1960: 14 Oct., 987; 11 Nov., 1415
1961: 28 Apr., 1321; 18 Aug., 486

Syringes, Radiation Shielded

Hamilton Co., Inc.
1961: 12 May, 1448; 21 July, 205

Tachometers

VirTis Co., Inc.
1961: 24 Mar., 796

Teaching Equipment, Physiological

Harvard Apparatus Co.
1960: 11 Nov., 1413

Teaching Equipment, Radiation
See Demonstration equipment, nuclear

Telescopes

Criterion Manufacturing Co.
1961: 20 Jan., 232; 17 Feb., 498; 24 Mar., 954; 21 Apr., 1264; 19 May, 1614
Edmund Scientific Co.
1960: 25 Nov., 1519
1961: 20 Jan., 151; 24 Mar., 829; 21 Apr., 1186; 19 May, 1533; 18 Aug., 434; 22 Sept., 781
Unitron Instrument Co.
1960: 4 Nov., 1324; 18 Nov., 1506; 2 Dec., 1714
1961: 6 Jan., 54; 28 Apr., 1374; 1 Sept., 624

Temperature Circulators

Brinkmann Instruments, Inc.
1960: 9 Dec., 1780
1961: 22 Sept., 875

Temperature Controllers, Liquid

Brinkmann Instruments, Inc.
1960: 18 Nov., 1508; 9 Dec., 1774; 30 Dec., 1946
Bronwill Scientific, Div. of Will Corp.
1960: 21 Oct., 1070
1961: 24 Mar., 934; 14 Apr., 1138; 19 May, 1620
Instruments for Research and Industry
1961: 17 Feb., 514; 21 Apr., 1296; 19 May, 1653; 21 July, 233; 22 Sept., 883
LaPine Scientific Co.
1961: 21 Apr., 1264
Schuco Scientific, Div. of Schueler & Co.
1960: 2 Dec., 1681
Wilkens-Anderson Co.
1961: 22 Sept., 880

Temperature Controllers, Low Temperature

Lauda Instruments, Inc.
1961: 19 May, 1655; 16 June, 1929; 16 June, 1946; 18 Aug., 483; 22 Sept., 867
VirTis Co.
1961: 18 Aug., 501

Temperature Indicators, Paint

Curtiss-Wright Corp.
1961: 24 Mar., 898

Temperature Programmers, Linear

F & M Scientific Corp.
1960: 21 Oct., 1196; 11 Nov., 1346
1961: 22 Sept., 770

Temperature Recorders, Cryogenic

Texas Instruments, Inc.
1961: 24 Mar., 946

Test Tube Closures

Bellco Glass Inc.
1960: 21 Oct., 1163
1961: 8 Sept., 681

Test Tube Mixers

Beckman Instruments, Inc., Spinco Div.
1961: 23 June, IFC; 8 Sept., IFC
Clay-Adams
1961: 16 June, 1849; 18 Aug., 413; 22 Sept., 791
Scientific Industries, Inc.
1960: 21 Oct., 1158
1961: 17 Feb., 498; 16 June, 1950

Thermometers, Electronic (Thermistor)

Greiner, Emil, Co.
1961: 16 June, 1958
Tri-R Instruments
1960: 21 Oct., 1203; 2 Dec., 1672
1961: 22 Sept., 889
VirTis Co.
1961: 18 Aug., 501
Yellow Springs Instrument Co., Inc.
1960: 2 Dec., 1688

Timers, Laboratory

Scientific Glass Apparatus Co., Inc.
1960: 25 Nov., 1562
Standard Scientific Supply Corp.
1960: 2 Dec., 1698

Tissue Culture Equipment

Bellco Glass Inc.
1960: 30 Dec., 1949
Kontes Glass Co.
1961: 16 June, 1959
New Brunswick Scientific Co., Inc.
1961: 17 Mar., 769; 12 May, 1495; 9 June, 1837; 8 Sept., 683

Tissue Grinders
See Homogenizers, tissue

Titrators, Automatic

Brinkmann Instruments, Inc.
1961: 14 Apr., 1137; 21 Apr., 1301; 22 Sept., 847
Buchler Instruments, Inc.
1961: 17 Feb., 521
Coleman Instruments, Inc.
1961: 28 Apr., 1318; 22 Sept., 779
Fisher Scientific Co.
1961: 24 Mar., 842; 26 May, 1725
Danube International Trade Corp.
1960: 21 Oct., 1148
Polarad Electronics Corp., Scientific Instruments Div.
1960: 21 Oct., 1045; 11 Nov., 1363
1961: 31 Mar., IBC
Sargent, E. H., & Co.
1961: 18 Aug., 421
Standard Scientific Supply Corp.
1961: 20 Jan., 228; 22 Sept., 858
Welwyn International Inc.
1960: 21 Oct., 1050
1961: 20 Jan., 146

Titrators, Micro

Beckman Instruments, Spinco Div.
1961: 23 June, IFC; 8 Sept., IFC
Cooke Engineering Co.
1961: 6 Oct., 1017
Intercontinental Scientific Corp.
1961: 16 June, 1941
Thomas, Arthur H., Co.
1961: 14 July, BC

Tubing Connectors

Beckman Instruments, Inc., Scientific and Process Instruments Div.
1960: 25 Nov., 1569

Tubing, Glass

Kimble Glass Co.
1960: 14 Oct., 983

Tubing, Plastic

Nalge Co., Inc.
1961: 19 May, 1623; 18 Aug., 488
U.S. Stoneware
1961: 24 Mar. 916; 19 May, 1615; 22 Sept., 864

Typewriter Symbols, Scientific

Mechanical Enterprises Inc.
1961: 22 Sept., 854; 6 Oct., 1021

Ultrasonic Cleaners

Edmund Scientific Co.
1961: 19 May, 1533
Will Corp.
1961: 17 Feb., 531

Ultrasonic Disintegrators
See Disintegrators, ultrasonic

Ultraviolet Analyzers

Buchler Instruments Inc.
1961: 21 July, 219; 18 Aug., 486
Canal Industrial Corp.
1960: 21 Oct., 1171; 2 Dec., 1679
1961: 17 Feb., 515
Gilson Medical Electronics
1961: 7 July, 60
L K B Instruments, Inc.
1960: 16 Dec., 1791
1961: 24 Mar., 811; 21 Apr., 1158

Vacuum Distillation Equipment
See Stills, vacuum

Vacuum Gauges

Central Scientific Co.
1960: 14 Oct., 1022
Gilmont, Roger, Instruments Inc.
1961: 21 Apr., 1299; 16 June, 1961; 22 Sept., 897
Greiner, Emil, Co.
1961: 22 Sept., 760
Hughes Aircraft Co., Vacuum Tube Products Div.
1961: 21 July, 224
Kinney Vacuum Div., New York Air Brake Co.
1960: 21 Oct., 1177; 2 Dec., 1719
1961: 17 Feb., 497
NRC Equipment Corp.
1961: 24 Mar., 949; 19 May, 1644; 16 June, 1949
Smith, Arthur F., Inc.
1960: 11 Nov., 1421; 2 Dec., 1680
1961: 24 Mar., 938

Vacuum Leak Controllers

Granville-Phillips Co.
1960: 7 Oct., 970

Valves, Needle, Teflon

Greiner, Emil, Co.
1961: 17 Feb., 498

Valves, Vacuum

Kinney Vacuum Div., New York Air Brake Co.
1961: 24 Mar., 905

Vapor Pressure Apparatus

Fisher Scientific Co.
1961: 9 June, 1789

Viscometers

Ferranti Electric Inc.
1960: 21 Oct., 1159
Polarad Electronics Corp., Scientific Instruments Div.
1960: 21 Oct., 1045; 11 Nov., 1363
1961: 31 Mar., IBC

Warburg Apparatus

Bronwill Scientific, Div. of Will Corp.
1960: 21 Oct., 1070
1961: 17 Feb., 521; 10 Mar., 713; 7 Apr., 1085; 19 May, 1629; 16 June, 1941; 18 Aug., 507
Gilson Medical Electronics
1960: 21 Oct., 1182
1961: 24 Mar., 940; 5 Aug., 296
Scientific Glass Apparatus Co., Inc.
1961: 17 Feb., 409
Will Corp.
1960: 21 Oct., 1041

Washers, Glassware
See Glassware washers

Waste Containers, Radioactive

Blickman, S., Inc.
1961: 16 June, 1936; 18 Aug., 507

Water Baths

Blue M Electric Co.
1960: 2 Dec., 1708
Hotpack
1961: 19 May, 1626
Precision Scientific Co.
1961: 17 Feb., 510; 21 Apr., 1286; 21 July, 151
Research Specialties Co.
1961: 24 Mar., 900
Schuco Scientific, Div. of Schueler & Co.
1961: 20 Jan., 236
Scientific Glass Apparatus Co., Inc.
1961: 23 June, 2026
Thermolyne Corp.
1961: 10 Mar., 714
Wilkens-Anderson Co.
1961: 19 May, 1646; 22 Sept., 880

Water Pressure Controllors

Buchler Instruments, Inc.
1961: 20 Jan., 140; 24 Mar., 904

Water Purifiers

Barnstead Still & Sterilizer Co.
1960: 2 Dec., 1720

Water Standard, Triple Point

Trans-Sonics, Inc.
1961: 19 May, 1642; 16 June, 1959; 22 Sept., 890

Weights, Balance

Ohaus Scale Corp.
1961: 22 Sept., 894

X-ray Diffraction Equipment

Engis Equipment Co.
1961: 24 Mar., 942; 22 Sept., 867
Erb & Gray Scientific, Inc.
1961: 1 Sept., 583
Radio Corporation of America
1961: 17 Feb., 408; 21 July, 146

Zone Refiners

Fisher Scientific Co.
1961: 10 Feb., 350; 7 Apr., 1038

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7 October 1960 through 6 October 1961

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Animal Research Center
Bainbridge, N.Y.

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Atkins Technical Inc.
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Glasgow, W. 3, Scotland

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Canner's, Inc.
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United States Testing Co., Inc.
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Wilkens Instrument & Research Inc.
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Wisconsin Alumni Research Foundation
P.O. Box 2217, Madison 1, Wis.

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PERSONNEL PLACEMENT

CLASSIFIED: Positions Wanted 25¢ per word, minimum charge $4. Use of Box Number counts as 10 additional words. Payment in advance is required.

COPY for ads must reach SCIENCE 2 weeks before date issue (Friday of every week).

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Editor, formerly with Forest Service, seeks freelance assignments by mail. Wendell Smith, Rock Harbor, Orleans, Mass. 10/20

(a) **Plant Pathologist,** Ph.D., desires academic assignment teaching and research; interested botany, microbiology, mycology, agricultural chemistry. (b) **Biochemist,** Ph.D., special work in electron microscopy, radiochemistry, nucleonics; interested research. Communicate **Science Division, The Medical Bureau, Inc.,** Burneice Larson, *Chairman,* 900 North Michigan Avenue, Chicago 11, Illinois.

POSITIONS OPEN

Supervisor Clinical Pathology. Excellent opportunity for a male college graduate with a minimum of 5 years' experience in a clinical laboratory including at least 2 years in a supervisory capacity. Will supervise technicians performing procedures in hematology, urinalysis and parisitology. Please write giving details, including salary requirement, to Miss Anne V. Cronin, Personnel Director, New England Medical Center, 37 Bennet Street, Boston, Massachusetts.

POSITIONS OPEN

(a) **Analytical Chemist,** well-known pharmaceutical firm, background organic chemistry essential; Midwest. (b) **Biochemist,** emphasis enzymology, energetics, intermediary metabolism; to $10,000; East. (c) **Pharmacologists** with CNS or cardiovascular background; East. (d) **Chemistry Professor,** $7500 for 9 months; Midwest. (e) **D.V.M.,** $10-$15,000, background experimental pathology; Midwest. (f) **Research Physiologist,** neurophysiology experience, to $8995; West. (g) **Clinical Biochemist,** 210-bed hospital, $8000-$12,000; Midwest. (h) **Immunologist,** well-known research center, $7000-$8000 up; Midwest. (i) **Faculty Appointments,** physics, liberal arts college, noted health resort; West. **Science Division, Medical Bureau, Inc.,** Burneice Larson, *Chairman,* 900 North Michigan Avenue, Chicago 11, Illinois.

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Ph.D. with special training in neuropharmacology. Senior and responsible position. Administrative ability, for expanding research department of upstate New York pharmaceutical company.

Box 200, SCIENCE

Ph.D.
MICROBIOLOGIST

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William J. Sumner
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Postdoctoral Fellowship in Biochemistry, involving blood proteins, available immediately. $6000 to begin, partially tax free, no tuition. For further information write to Assistant Director for Education, Office of Education,
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The Market Place

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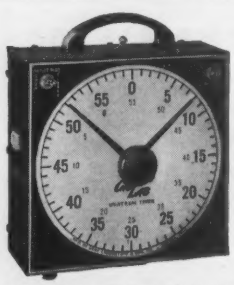

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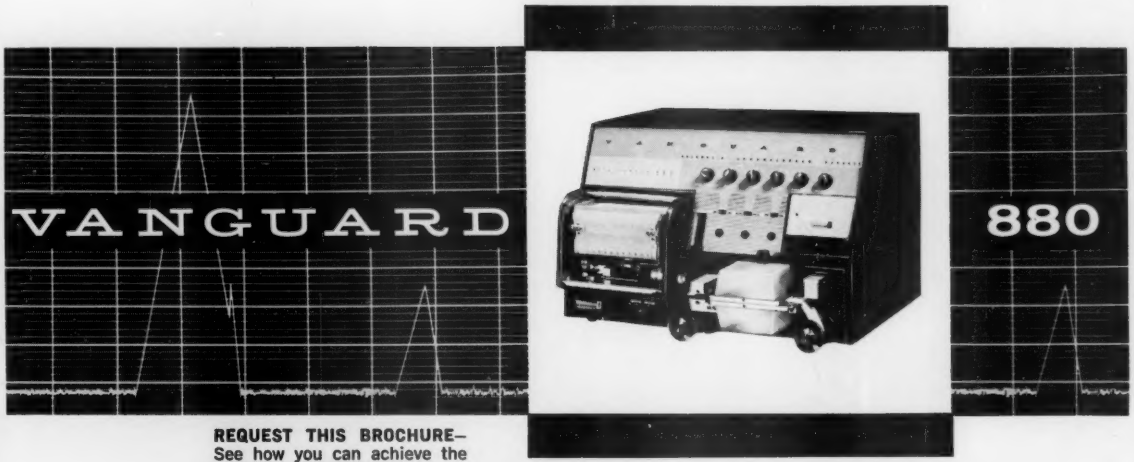
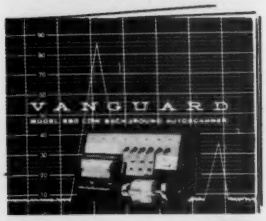


REQUEST THIS BROCHURE—See how you can achieve the highest detection efficiency available for chromatogram scanning. Booklet outlines distinctive features and lists all operational characteristics of the Model 880 AUTOSCANNER.



- Features 4 pi scanning—counts radiation on both sides of strip simultaneously
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- Completely transistorized for longer, more reliable performance
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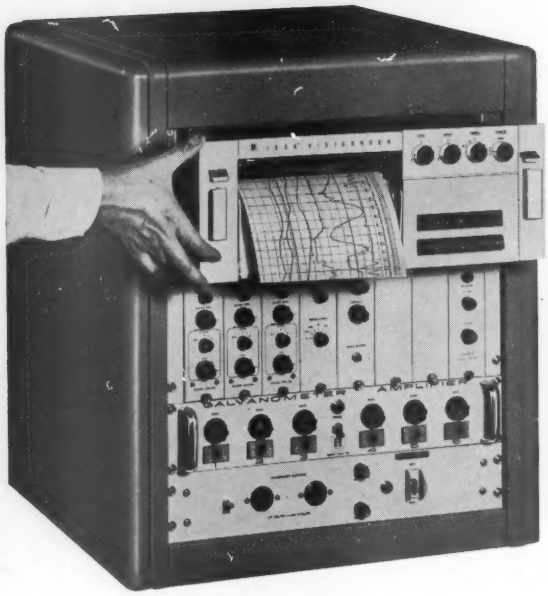

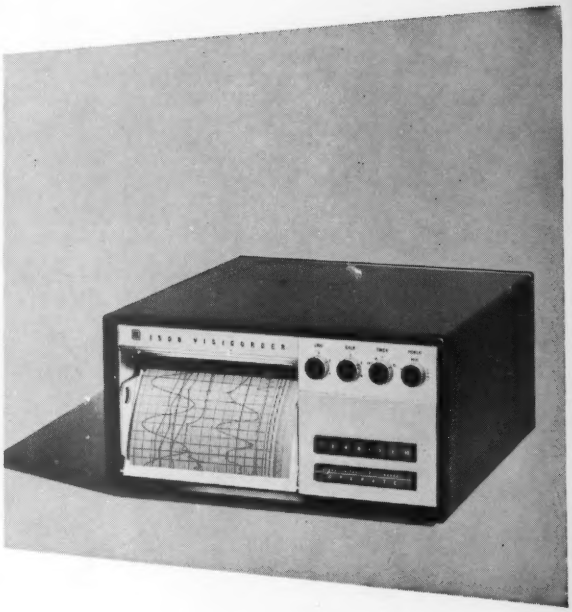

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